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The Blast Furnace and Steel Plant

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The Making of a Mill

BACK in the year 1844, a young man, 22 years of age, left the farm of his father imbued with the idea that his future lay, not as a tiller of the soil, but as an engineer. He spent considerable time as a mechanic in a boiler shop until eventually the fascination for the manufacture of iron became so alluring that he sought employment in the nearest iron mill—that of Moore and Hoover, at Norristown, Pa.

He was unlearned and without experience, but he possessed determination and was so much in earnest on presenting himself, that the manager of the plant remarked, "Young man, I like thy looks and I will give thee work."

Each day for 12 hours he labored at the mill and at night spent his spare time watching the puddlers and seeking knowledge whereby he might satisfy an innate craving for self development. The interest and application displayed attracted the attention of the company officials with the result that he was soon advanced to a much higher position.

In time the young man became convinced that he had quite well exhausted the field for experience in his present position, hence in 1854, he accepted employment with the Cambria Iron Company. Here he again attracted attention by his persistency and utter disregard of hours of labor. He had set his mind on a goal and could not be dissuaded.

At 10 o'clock in the morning of June 29, 1859, an iron pile was drawn from a furnace and passing through the rolls of the first three high mill, was converted into a rail as John Fritz stood by and witnessed the culmination of a dream achieved only after he had passed through years of arduous toil and a "merciless fire of vindictive ridicule."

John Fritz had characteristics akin to that of the metal he subjugated.

The Manufacture of Some Foreign Rails*

Krupp Rails from Basic Open-Hearth Bottom Poured Ingots of Unusual Length Made for an American Railroad—Roller Straightening Method Used—Test Results Shown

By C. W. GENNET, Jr.†

ANNOUNCEMENT was made in the spring of 1926 that the Boston & Maine R. R. Company had contracted with the well known German steelmakers, Messrs. Fried Krupp, for the manufacture of 15,000 tons of basic open-hearth steel rails at the Rheinhausen Works, for delivery to Boston, Mass.

The manufacture of rails in the United States has for many years been almost a national pride, and as this feeling is chiefly the result of a long-time liberal and consistent patronage of American rails by American railroads, it is not strange that this somewhat unusual announcement should arouse more than ordinary interest. Since the end of the World War, the importation of foreign rail has been fairly large, principally because the newly created economic conditions have rendered some American competition more difficult, but the tonnage imported, for the most part, has been made up of small orders for miscellaneous use; and the contract referred to constitutes the largest single importation of foreign rail in over 10 years. In 1915, the Algoma Steel Company of Salut Ste. Marie, Canada, suplied the Illionis Central R. R. with 30,000 tons of rails,‡ and various other American roads with smaller amounts. In 1902, 1903 and 1904, large tonnages of rail from abroad were purchased, the Louisville & Nashville R. R. alone obtaining 30,000 tons from German mills.

It is the object of this paper to present, in what is believed to be a new and concise form, figures showing the production and consumption of rails in the United States, and to record some of the testing and inspection results of the recent Krupp rails; also, to direct attention to two quite unique departures from American practice that were regular features of the Krupp process and which are worthy, it is thought, of careful study.

Production and Consumption of Rails in the United States

Table 1 shows the tonnage of rail produced in the United States and the amount imported, exported, and consumed by years since 1849. That, evidently, was the first year of record, for the statistics of the American Iron and Steel Institute and its predecessor, the American Iron and Steel Association (to both of whom I am indebted), fail to disclose earlier figures. The table shows the growth of the iron industry in America; the transition from iron rails to those of Bessemer steel; and clearly marks the beginning and rapid growth of the open-hearth steel process with respect to rails. It should also help to dispel certain fears that may be held regarding the serious effect of the amount of the importations on the industry. In the last 36 years—that is, since 1890—a total of only 637,555 tons of rail has been brought into the United States against 87,710,350 tons actually rolled and 9,767,262 tons exported. Thus, on the average, for every 1,000 tons of rail rolled in the United States there have been 7 tons imported and 11 tons exported. The Iron and Steel Division of the United States Department of Commerce has furnished figures showing that from 1890 to 1925 inclusive, the imported rail came from the following countries: 41.7 per cent from Canada; 24.2 per cent from Belgium; 24.0 per cent from Germany; 4.7 per cent from United Kingdom; 2.6 per cent from Netherlands; 1.8 per cent from France.

Manufacture, Testing and Inspection of Recent Krupp Rails

The Boston & Maine R. R., largely double tracked, operates a total of 4,287 track miles, located principally in the states of Maine, New Hampshire, Vermont and Massachusetts. In those somewhat mountainous New England states, conditions occur which demand a high standard of track maintenance and rail steel. Temperature changes are quite extreme, and the traffic, especially that to which some of the Krupp rail will be subjected, is heavy and dense with slow-speed freight trains alternating with high-speed passenger service. The maximum grade is about 1.45 per cent and approximately 36 per cent of the main line trackage consists of curves. While train movements on main-line curves up to 8.5 deg. are without speed restrictions; on other main-line curves of a maximum of 15 deg., the speed is limited. The maximum axle loads of the Santa Fe type of freight locomotives used are 62,300 lb. and Pacific type passenger locomotives have axle loads of 54,000 lb.

The Boston and Maine contract covered 11,000 tons of 100-lb. rail of what is known as the New York, New Haven and Hartford section, and 4,000 tons of 85-lb. rail of the A. S. C. E. section. The important features of these sections are shown in Table 2.

The contract provided that the basic open-hearth steel rails were to conform to the specifications of the American Railway Engineering Association as adopted on March 12, 1925. These specifications were slightly modified to permit all of the drop tests to be made on pieces resting head up in the drop-testing machine, and as the Krupp drop-testing machine had a tup weighing a metric ton (2,204 lb.) the height of the drop test as specified was changed to 17.2 ft. for the 100-lb. rail, and 14.6 ft. for the 85-lb. rail. In view of the fact that the supports of the Krupp machine were on a solid foundation rather than on springs, as in this country, the testing was probably a little more severe than would otherwise be the case.

The rails were rolled at the Rheinhausen Works from steel made by the straight open-hearth process, in four tilting basic-lined furnaces, each of approximately 120 tons capacity. The charges, mostly all

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*Paper read at February meeting, American Institute of Mining and Metallurgical Engineers.

†Chicago, Ill.

‡Robert W. Hunt and C. W. Gennet, Jr.: The Nick and Break Test in the Inspection of Steel Rails. Proc. Amer. Railway Engng. Assn. (1916) 17, 751.

TABLE 1.—*Production and Consumption of Rails in the United States*

	Production Gross Tons				Gross Tons		
Year	Open-hearth	Bessemer	Iron	Total	Imports	Exports	Consumption
1849	-	-	21,712	21,712	61,752	-	83,464
1850	-	-	39,360	39,360	142,035	-	181,395
1851	-	-	45,181	45,181	202,098	-	247,279
1852	-	-	55,784	55,784	263,169	-	318,953
1853	-	-	78,450	78,450	320,351	-	398,801
1854	-	-	96,443	96,443	303,070	-	399,513
1855	-	-	123,816	123,816	136,624	-	260,440
1856	-	-	160,730	160,730	166,601	-	327,331
1857	-	-	144,570	144,570	192,112	-	336,682
1858	-	-	146,171	146,171	81,155	-	227,326
1859	-	-	174,513	174,513	74,962	-	249,475
1860	-	-	183,070	183,070	130,901	-	313,971
1861	-	-	169,480	169,480	79,810	-	249,290
1862	-	-	190,993	190,993	9,095	-	200,088
1863	-	-	246,221	246,221	18,308	-	264,529
1864	-	-	299,436	299,436	127,193	-	426,629
1865	-	-	318,118	318,118	56,541	-	374,659
1866	-	-	384,623	384,623	105,248	-	489,871
1867	-	2,277*	410,319	412,596	145,580	-	558,176
1868	-	6,451	445,972	452,423	223,287	-	675,710
1869	-	8,616	521,372	529,988	279,609	-	809,597
1870	-	30,357	523,214	553,571	356,387	-	909,958
1871	-	34,152	658,467	692,619	505,537	297	1,197,859
1872	-	83,991	808,866	892,857	473,973	1,082	1,365,748
1873	-	115,192	679,520	794,712	231,046	335	1,025,423
1874	-	129,414	521,848	651,262	96,706	1,122	746,846
1875	-	259,699	447,901	707,600	17,364	1,080	723,884
1876	-	368,269	417,114	785,383	256	3,180	782,459
1877	-	385,865	296,911	682,776	31	6,647	676,160
1878	8,390	491,427	288,295	788,112	9	8,354	779,767
1879	8,168	610,682	375,143	993,993	39,417	3,066	1,030,344
1880	12,157	852,196	440,859	1,305,212	259,543	958	1,563,797
1881	22,515	1,187,770	436,233	1,646,518	344,929	611	1,990,836
1882	20,325	1,284,067	203,459	1,507,851	200,113	3,220	1,704,744
1883	8,202	1,148,709	57,994	1,214,905	34,801	2,308	1,247,398
1884	2,384	996,983	22,821	1,022,188	2,829	6,034	1,018,983
1885	4,279	959,471	13,228	976,978	2,189	7,757	971,410
1886	4,692	1,574,703	21,142	1,600,537	41,587	2,644	1,639,480
1887	17,145	2,101,904	20,591	2,139,640	137,830	549	2,276,921
1888	4,698	1,386,277	12,725	1,403,700	63,037	6,908	1,459,829
1889	2,988	1,510,057	9,159	1,522,204	6,217	9,325	1,519,096
1890	3,588	1,867,837	13,882	1,885,307	204	16,947	1,868,564
1891	5,883	1,293,053	8,240	1,307,176	253	11,239	1,296,190
1892	3,819	1,537,588	10,437	1,551,844	347	7,982	1,544,209
1893	968	1,129,400	6,090	1,136,458	2,888	19,876	1,119,470
1894	1,085	1,016,013	4,674	1,021,772	300	13,556	1,008,516
1895	697	1,299,628	5,810	1,306,135	1,447	15,599	1,291,983
1896	705	1,116,958	4,347	1,122,010	7,796	73,131	1,056,675
1897	500	1,644,520	2,872	1,647,892	415	148,221	1,500,086
1898	1,220	1,976,702	3,319	1,981,241	200	301,903	1,679,538
1899	523	2,270,585	1,592	2,272,700	2,134	277,714	1,997,120
1900	1,333	2,383,654	695	2,385,682	1,448	361,619	2,025,511
1901	2,093	2,870,816	1,730	2,874,639	1,905	318,956	2,557,588
1902	6,029	2,935,392	6,512	2,947,933	63,522	67,666	2,943,789
1903	45,054	2,946,756	667	2,992,477	95,555	30,837	3,057,195
1904	145,883	2,137,957	871	2,284,711	37,776	416,250	1,906,237
1905	183,264	3,192,347	318	3,375,929	17,278	295,023	3,098,184
1906	186,413	3,791,459	15	3,977,887	4,943	328,036	3,654,794
1907	252,704	3,380,025	925	3,633,654	3,752	338,906	3,298,500
1908	571,791	1,349,153	71	1,921,015	1,719	196,510	1,726,224
1909	1,256,674	1,767,171	-	3,023,845	1,542	299,540	2,725,847
1910	1,751,359	1,884,442	230	3,636,031	7,861	353,180	3,290,712
1911	1,676,923	1,053,420	234	2,822,790	3,414	420,874	2,405,330
1912	2,105,144	1,099,926	-	3,327,915	3,780	446,473	2,885,222
1913	2,527,710	817,591	-	3,502,780	10,408	460,553	3,052,635
1914	1,525,851	323,897	-	1,945,095	22,571	174,680	1,792,986
1915	1,775,168	326,952	-	2,204,203	78,525	391,379	1,891,349
1916	2,269,600	440,092	-	2,854,518	26,299	540,828	2,339,989
1917	2,292,197	533,325	-	2,944,161	9,263	512,669	2,440,755
1918	1,945,443	494,193	-	2,540,892	8,705	453,537	2,096,060
1919	1,893,250	214,121	-	2,203,843	17,008	652,443	1,568,408
1920	2,334,222	142,899	-	2,604,116	45,684	594,628	2,055,172
1921	2,027,215	55,559	-	2,178,818	22,048	321,822	1,879,044
1922	2,033,000	22,317	-	2,171,776	26,629	277,090	1,921,315
1923	2,738,779	25,877	-	2,904,516	29,706	267,409	2,666,813
1924	2,307,653	16,069	-	2,433,332	43,368	208,496	2,268,194
1925	2,691,823	9,687	-	2,785,257	36,872	151,690	2,670,439

*First year of Commercial Production

NOTE:- The production of rerolled and electric steel rails has been omitted in the above but included in the total produced.

cold, consisted of about 75 per cent mill scrap and 25 per cent pig iron made from Swedish and Morocco ore. Furnace operations were stopped when the bath showed the proper carbon content, and as ferromanganese was added to the furnace the only necessary addition to the ladle was ferrosilicon, and no additions were made to the metal in the ingot molds. It required approximately 10 hrs. to make a complete melt. Because the teeming ladles were inadequate to hold all of the 120 tons comprising a furnace melt, many of the melts were tapped into two ladles, the metal of each ladle then being considered a heat. The diameter of the nozzle in the ladle was 1.56 in.

The ingots were bottom cast in groups of four. The molds, slurried with tar, stood on a cast-iron base plate grooved for runner bricks connected to a central riser. The molten steel from the ladle nozzle entered the central riser through a hole 3 in. in diameter and flowed thence through 1½ in. holes in the runner bricks to each of the four molds. The ingots cast were 25 in. square at the bottom and 21 in. square at the top, with 4-in. radii at the corners. The ingots were poured 88 in. high for the 100-lb. rail and 100 in. high for the 85 lb., and weighed respectively about 12,500 lb. and 13,500 lb. It required about 15 min. to bottom pour a group of four ingots, and after approximately 50 min. the molds were taken off and the ingots charged to the pits.

The pits consisted of three groups, each of 20 holes, of the old style "soaking pits" in which no reheating was possible. For fear, however, that the steel for these rails would be insufficiently hot for good results in rolling, these rail ingots were charged to other pits consisting of three groups, each of 16 holes, fired with coke-oven gas. Each hole held but one ingot. After about 2 hours in the pits, the ingots were bloomed and rolled direct into rails.

The blooming was in a two-high 43-in. engine-driven mill, rolling the top end of the ingot first and reducing it in 21 passes, after six turns, to a bloom approximately 8⅜ by 7⅞ in. After a top discard of about 12 per cent and a bottom discard of 5 per cent, the blooms went without reheating into a three-high, 33½-in. roughing stand and a three-high 33½-in. finishing stand, both being engine driven. The blooms received nine passes in the rail mill for the 100 lb. section and 11 for the 85 lb., so that the total number of passes from the ingot to the rail was 30 or 32, depending on the section being rolled. The rails were sawed to length by a single hot saw, cutting each rail slightly long to allow for milling the ends to practically an exact length of 39 ft. It is important to note that there was no hot cambering machine, the rails going on to one of the four hot beds direct from the mill and hot saws, and being neither spaced nor turned while cooling on the hot beds.

TABLE II

Important Features of Two Boston and Maine Sections.

	Weight per Yard 100-lb.	 85-lb.
Section	N.Y., N.H.&H.	A. S. C. E.
Height of rail, inches	6	5 3/16
Width of base, inches	5½	5 3/16
Width of head, inches	2¾	2 9/16
Thickness of web, inches	19/32	9/16
Area head, square inches	4.04	3.50
Area web, square inches	2.33	1.75
Area base, square inches	3.40	3.08
Per cent metal in head	41.4	42.0
Per cent metal in web	23.8	21.0
Per cent metal in base	34.8	37.0
Moment of inertia	47.1	30.0
Section modulus (base)	16.4	12.1

Table 3 gives the results of the rolling, inspection and testing of the rails. The inspection was conducted by American inspectors sent abroad for this particular work and it can be assumed, therefore, that the surface inspection of the Krupp rails was in every way comparable with the practice that would be followed at American mills. The testing was in accordance with the requirements of the specification, except as already noted. It is especially significant to observe that no "X-Rayls" were produced. "X-Rayls," it will be recalled, are the result of finding the fracture of at least one of the test pieces from each heat either piped or segregated. This matter is commented upon later at greater length.

TABLE III

Rolling and Testing Results.

	85-lb.		100-lb.		Total	
	No.	%*	No.	%*	No.	%*
Furnace melts made	45	...	134	...	149	...
Heats cast and rolled	88	...	242	...	330	...
Ingots rolled	920	...	2,807	...	3,727	...
Rails per ingot (nominal)	10	...	8	...		...
Rails rolled	9,119	...	21,784	...	30,903	...
Rails restraightened (following inspct.)	102	1.1	357	1.6	459	1.5
Cut for flaws	4	...	106	...	110	...
Cut for other reasons	386	...	437	...	823	...
Total short rails	390	4.2	543	2.5	933	3.0
Made No. 2 for flaws	456	...	1,421	...	1,877	...
Made No. 2 for other reasons	0	...	31	...	31	...
Total No. 2 rails	456	5.0	1,452	6.6	1,908	6.2
Rejected account surface defects	250	...	713	...	963	...
Rejected account other reasons	10	...	8	...	18	...
Total rejected (excepting for tests)	260	2.8	721	3.3	981	3.2
Rejected account failure at drop test:						
"A" rails	26	...	135	...	161	...
"B" rails	26	...	71	...	97	...
"C" etc., rails	56	...	290	...	346	...
Total rejected at drop test	108	1.2	496	2.3	604	1.9
Total all rej'tions	368	4.0	1,217	5.6	1,585	5.1
Made "X-Rayls"	0	...	0	...	0	...
Heats on which rails failed at drop test:						
"A" rails	3	...	11	...	14	...
"B" rails	3	...	6	...	9	...
"C" rails	1	...	4	...	5	...
Total heats rejected at drop test	1	...	4	...	5	...

*Per cent of number of rails rolled.

Table 4 shows the chemical composition of the Krupp rails. It is mostly in line with American practice, except perhaps that the sulphur content is low. The ability of the mill to keep the carbon content well on the high side of the mean of the specified range is easily recognized.

Table 5 shows the amount of each classification of rail that was shipped. The specification provided for dividing the acceptable rails into six different classes, each identifiable by the color of paint used on the

TABLE IV
Chemical Composition.

	Specified	Obtained			
		85 lb.		100 lb.	
		Range	Average	Range	Average
	%	%	%	%	%
Carbon	0.62–0.77	0.63 –0.77	0.69	0.64 –0.77	0.70
Manganese	0.60–0.90	0.66 –0.88	0.78	0.61 –0.90	0.77
Phosphorus not over .	0.04	0.015–0.038	0.029	0.011–0.040	0.025
Sulphur ...		0.020–0.040	0.028	0.017–0.037	0.028
Silicon not less	0.15	0.15 –0.23	0.18	0.15 –0.24	0.19

Number of Heats with Each Per Cent of Carbon Content

Carbon Content %	No. of heats obtained 85 lb.	100 lb.	Total	Remarks
0.62	0	0	0	158 heats = 48 per cent were below the mean of the carbon range specified.
0.63	3	0	3	
0.64	7	15	22	
0.65	6	25	31	
0.66	6	21	27	
0.67	5	13	18	
0.68	8	27	35	
0.69	7	15	22	
0.70	6	4	10	172 heats = 52 per cent were above the mean of the carbon range specified.
0.71	12	30	42	
0.72	6	22	28	
0.73	7	26	33	
0.74	7	15	22	
0.75	4	24	28	
0.76	3	4	7	
0.77	1	1	2	
Total ..	88	242	330	

ends. These results on the Krupp rails are at once comparable with results of American practice, and carefully kept figures covering approximately 450,000 tons of rails rolled to this specification at the different mills of the United States* are shown in Table 6 in comparison with those on the Krupp rails.

Fig. 1 shows the amount of deflection obtained by the drop tests on the Krupp rails and also the results of the ball indentation tests. Deflection on the Krupp rails are not directly comparable with American practice chiefly because the height of the drop was different and the supports for the test pieces on a solid anvil in one case as against a spring-supported one in the other. The trend of the curves is, however, quite characteristic.

Outstanding Features of Krupp Practice

Two notable departures from American practice on rails were outstanding features of the Krupp practice. One was the bottom-casting of the ingots, and the other—perhaps of greater importance—was the fact that all the rails were straightened by passing through a roller straightening machine, the common type of gag press being used only as a last resort for rails that the machine would not make straight.

Notable Results of Bottom-casting—Probably the most important requisite of rails for many years has been their soundness; i. e., the freedom of the metal from pipe and segregation. This matter has been repeatedly discussed, and various devices of ingot practice and of testing have been tried whereby the presence of piping and its accompaniment could be either eliminated or restricted. An extra price is sometimes paid for rails with the understanding that an abnormal top discard, frequently as much as 25 per cent shall be made for each ingot. Specifications almost invariably have been drawn with some provision whereby the tendency for interior defects in the top rails of ingots could be detected, and the American Railway Engineering Association specification, under which these Krupp rails were rolled, requires that a classification known as "X-Rayls" be made of those whose fractured test pieces show interior defects; meaning, chiefly, piping and segregation. A large tonnage of American rails tested in the past year, previously referred to, showed that on the average 2.2 per cent of the total shipments were "X-Rayls," but there were none among the Krupp rails. The Krupp ingots were large, in fact heavier, because of being taller, than most American rail ingots; and, according to the inspectors, the steel, for obvious reasons, was poured very hot, yet there was apparently complete freedom from piping. In view of the fact that a great many observations were made of the fractures of "A" rail test pieces, this is indeed a remarkable result, for which bot-

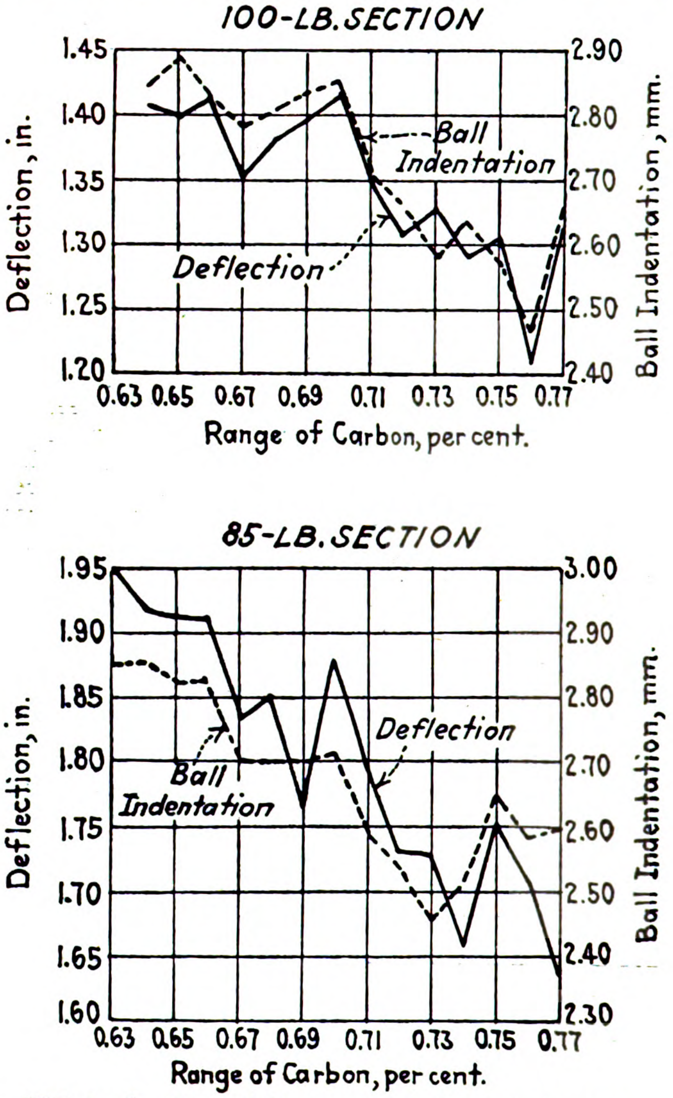

FIG. 1—Graphs of deflection and ball indentation tests.

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*C. W. Gennet, Jr.: The New Rail Specifications and Their Results. Railway Age (September 4, 1926) 81, 430.

TABLE V—Amount of Each Classification of Rail Shipped.

Classification	Ends of rail painted	Amount of Rail Shipped 85 lb. Pounds	Per cent*	100 lb. Pounds	Per cent*	Total Pounds	Per cent*
No. 2 rail	White	498,812	5.2	1,889,677	7.1	2,388,489	6.6
"X-Rayl"	Brown	None	0.0	None	0.0	None	0.0
"A" rail	Yellow	837,373	8.7	2,903.792	10.9	3,741,165	10.4
Less than 39 ft. long	Green	636.799	6.6	1,105.562	4.2	1,742,361	4.8
High carbon	Blue	3,957,539	41.4	10,405.207	39.2	14.362,746	39.8
All other rail	No paint	3,646,281	38.1	10 242,387	38.6	13,888,668	38.4
Total		9,576,804 = Tons 4,275	Lb. 804	26,546,625 = Tons 11,851	Lb. 385	36,123,429 = Tons 16,126	Lb. 1,189

*Percentage of toal shipped.

tom-casting must have been largely responsible. In fact, the inspector in charge of the work writes as follows:

> Regarding bottom-pouring, after what I have seen here, I am strongly for it. At any rate, there is no other cause to which I can attribute the complete freedom from segregation and piping. Out of over 900 fractured rails which I have examined (to date) at the drop test, we have not found one piped rail; neither have we found any in the yard . . . Occasionally, in a test piece which broke on the first blow, we would find the appearance of slight segregation, but never sufficient to cause the rails to be classed as "X-Rayls," even if they have not already been rejected. I have made a number of drop tests from pieces cut from the bottom end of the last rail of the ingot, but have seen no sign of pipe or segregation. I also found that, as a general rule, these test pieces from the bottom of the ingot stood two more blows before fracture than did the regular test pieces from that heat.

Much has been written on the subject of the bottom-casting of ingots, and opinion of its efficacy apparently varies widely. American steelmakers frequently resort to bottom-casting when making ingots for some special purposes, but as far as known, ingots cast in this manner have not been rolled into rails. With the idea of ascertaining what the possible effect of bottom-casting in this case actually was, small sections were cut from the top end of the top four rails (lettered "A," "B," "C" and "D") and the bottom end of the last two rails (lettered "G" and "H"), all from the same eight-rail ingot, selected at random in the mill at the time of rolling. Sulphur prints were made of these sections and the chemical composition was also obtained on standard drillings (A. R. E. A. practice) from each sample. These results are shown in Fig. 2. While considerable segregation is indicated in the "B," or second, rail, at a location about 22 per cent from the top of the ingot, the other rails appear almost free from it and also fairly sound physically.

TABLE VI

Comparison of Percentages of Acceptable Rails.

Classification of Rail Shipped	Percentage of Total Shipments Krupp	Average American Practice
No. 2 rails	6.6	5.8
"X-Rayls"	None	2.2
"A" rails	10.4	12.9
Short length rails	4.8	4.1
High carbon rails	39.8	30.3
All other rails	38.4	44.6

Other of the Krupp rails were analyzed in order to obtain an idea of their chemical condition and the results are given in Table 7. These chemical analyses indicate that segregation is present in these large bottom-cast ingots, possibly to about the same extent as in the shorter and stubbier top-cast American ingots. The number of chemical tests made are also altogether too few, and it is hoped that trials of this method of casting ingots will soon be made with a view to ascertaining much more definitely the possible effect on segregation. As far as actual piping is concerned, the practice evidently has much to commend it, and it would not be surprising to find that, with the restricted tendency to pipe, the steel would be freer from segregation.

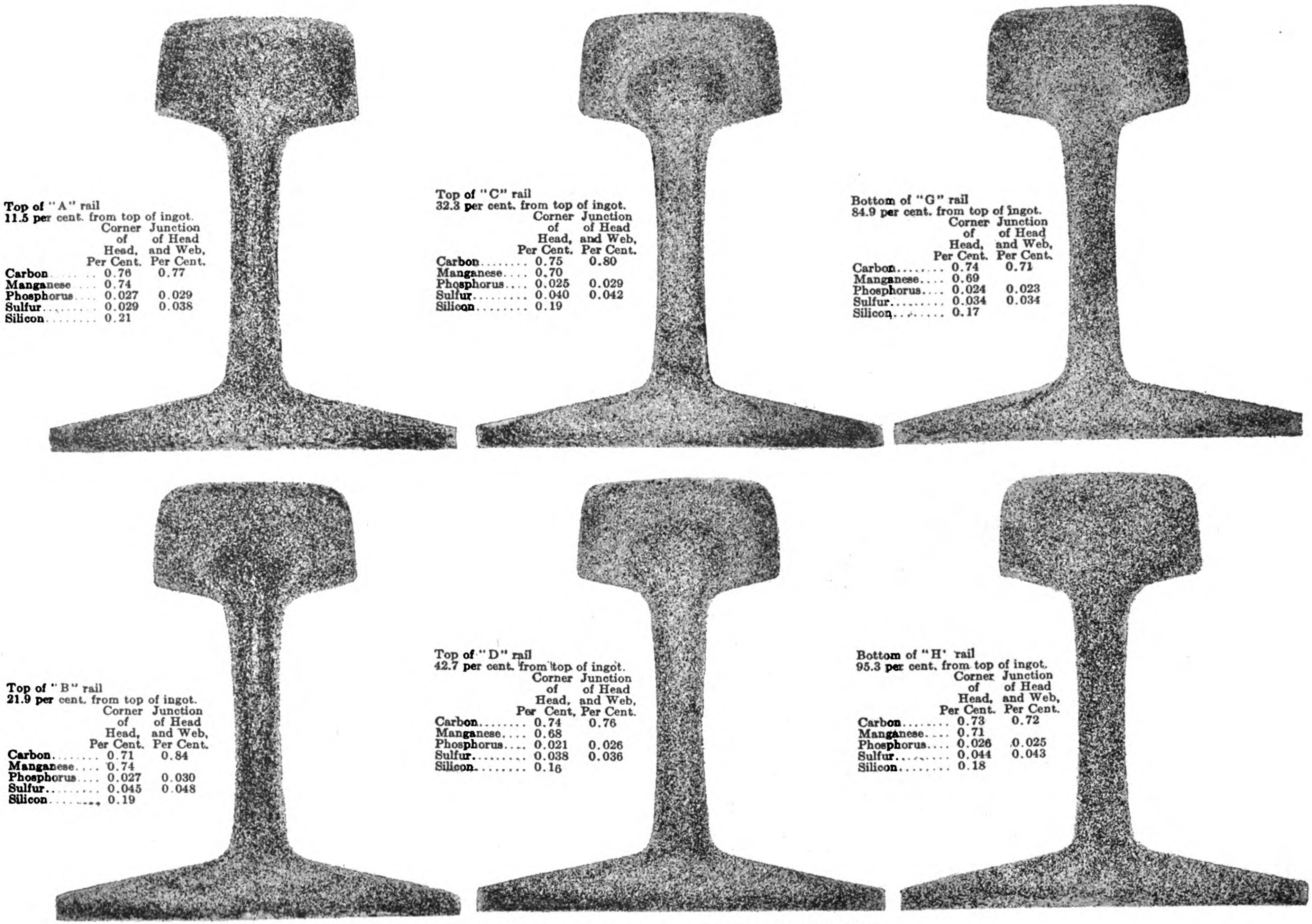
TABLE VII

Chemical Condition of Some Krupp Rails.

Sample from	Drillings from corner of head Carbon, Per cent	Phosphorus, Per cent	Sulphur, Per cent	Drillings from junction of head and web Carbon, Per cent	Phosphorus, Per cent	Sulphur, Per cent
Top of an "A" rail ...	0.79	0.046	0.045	1.01	0.050	0.029
Bot. of same "A" rail	0.72	0.037	0.035	0.86	0.034	0.035
Top of an "E" rail ..	0.75	0.048	0.042	0.69	0.049	0.036
Bot. of same "E" rail	0.74	0.050	0.039	0.71	0.050	0.042
Top of an "E" rail ..	0.67	0.050	0.044	0.71	0.055	0.045
Bot. of same "E" rail	0.71	0.042	0.050	0.70	0.038	0.042
Near cent. of a "C" rail	0.74	0.033	0.041	0.78	0.038	0.049

Straightening Rails—The standard practice, and the one in use for a great many years, of straightening rails in American mills is to use a gag press having fixed supports about 60 in. apart on which the cold, or hand-warm, rail rests. At the order of the "straightener," sighting the rail from one end, a gag is inserted on the rail between the supports and the moving ram of the press then bends the rail. Thus, by continued effort, the rail being moved lengthwise, and turned, as desired by the "straightener," the proper straightness is obtained quite regardless of the length of the rail. Prior to this straightening process, the rails are passed through a hot cambering machine located between the hot saws and the hot beds. The function of this machine, of course, is to put a curve in the hot rails so that they will be as near straight as practicable when cold, in spite of their unsymmetrical cross-section.

It seems quite unnecessary to comment on the probable abuse, if not actual damage, that a cold rail of high-carbon steel receives when being subjected to the blows of the straightening press, and it is to be



Top of "A" rail
11.5 per cent. from top of ingot.

	Corner of Head, Per Cent.	Junction of Head and Web, Per Cent.
Carbon	0.76	0.77
Manganese	0.74	
Phosphorus	0.027	0.029
Sulfur	0.029	0.038
Silicon	0.21	

Top of "B" rail
21.9 per cent. from top of ingot.

	Corner of Head, Per Cent.	Junction of Head and Web, Per Cent.
Carbon	0.71	0.84
Manganese	0.74	
Phosphorus	0.027	0.030
Sulfur	0.045	0.048
Silicon	0.19	

Top of "C" rail
32.3 per cent. from top of ingot.

	Corner of Head, Per Cent.	Junction of Head and Web, Per Cent.
Carbon	0.75	0.80
Manganese	0.70	
Phosphorus	0.025	0.029
Sulfur	0.040	0.042
Silicon	0.19	

Top of "D" rail
42.7 per cent. from top of ingot.

	Corner of Head, Per Cent.	Junction of Head and Web, Per Cent.
Carbon	0.74	0.76
Manganese	0.68	
Phosphorus	0.021	0.026
Sulfur	0.038	0.036
Silicon	0.16	

Bottom of "G" rail
84.9 per cent. from top of ingot.

	Corner of Head, Per Cent.	Junction of Head and Web, Per Cent.
Carbon	0.74	0.71
Manganese	0.69	
Phosphorus	0.024	0.023
Sulfur	0.034	0.034
Silicon	0.17	

Bottom of "H" rail
95.3 per cent. from top of ingot.

	Corner of Head, Per Cent.	Junction of Head and Web, Per Cent.
Carbon	0.73	0.72
Manganese	0.71	
Phosphorus	0.026	0.025
Sulfur	0.044	0.043
Silicon	0.18	

FIG. 2—Sulphur prints of cross-sections of Krupp rails.

remembered that each blow is one well beyond the elastic limit of the metal and that the gag frequently leaves an impression, and perhaps a depression, on the surface of the rail. This cold straightening process is expensive, always requiring a well paid straightener and gagger for each straightening press, the capacity of which may be roughly taken as 100 to 150 tons in eight hours.

The roller straightening machine in use at the Krupp Works consists of three top rolls and two bottom rolls, all power driven, and somewhat grooved to take a little of the head and base of the rails when head up in the machine. Vertical pinch rolls bearing on both sides of the web of the rails assist to feed the rails through. The general arrangement is as shown on Fig. 3. All of the rolls are movable and their position is largely dependent on the operator and his idea of the condition of the incoming rail. The whole machine is heavily housed. When rails of a different section are to be straightened, the grooves must be changed in the horizontal rolls, but this is easily accomplished because the grooves are really formed by collars on the main barrel of the roll, which are held on by large lock nuts.

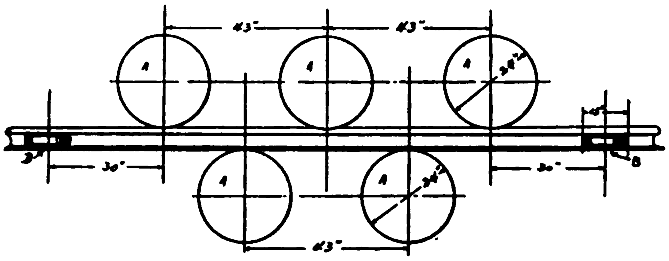


FIG. 3—Arrangement of rolls in roller straightening machine for heavy steel rails at Krupp works.

A=24-in. dia. power-driven rolls, slightly grooved for head and base of rails.
B=power-driven pinch rolls.

As previously mentioned, there was no hot cambering machine in the Krupp Works. Consequently, these rails, of which the cross-section was very unbalanced, cooled on the hot beds with a head-low sweep amounting to as much as 12 in. The feed mechanism on the entering side of the roller straightener was nevertheless adequate in every way to meet this condition, with the result that the rails were fed through the machine one after the other fairly fast. It required approximately 15 sec. for a 39-ft. rail to go through the machine, though this time could easily be reduced by running the machine somewhat faster. The temperature of the rails at the time of straightening was apparently of no great importance, and varied about as in this country, from stone cold to slightly warm.

It is obvious, from the arrangement of the rolls, that about 2 ft. of each end of the rail would be largely unaffected. Hence, if a short bend or kink occurred near the end of the rails, it had to be eliminated after roller straightening by going to the customary gag press. Likewise, if there was some condition that the roller straightener did not rectify, the rail was sent to the gag press. From 10 to 20 per cent of the rails had to be gagged, but if a hot cambering machine had been in use, it is altogether likely that it would have been necessary to deal with a much smaller proportion.

The rails straightened in this roller machine suffered considerable punishment. Of course, they had been strained well beyond the elastic limit, as was proved by the fact that they were quite free from the usual mill scale on the head and base, excepting at the extreme ends. The author, however, feels that this method of straightening, which could unquestionably be greatly improved by having good hot cambered rails to start with, is likely to be much less detrimental to rails than is the series of from 5 to 15 blows that the average rail receives in a gag press, and also is likely to result in a more accurate line and surface for the finished rail. In short, the very satisfactory results evidently obtained with the roller straightening machine abroad, on these high-carbon and unbalanced-section rails, appears to be a desirable advance in the finishing of rails; and there may be much, from the standpoint of costs as well as improvement of general conditions, to favor the introduction of similar equipment in American mills.

Acknowledgement

The author desires to express his thanks to William Salmon, who was in direct charge of the inspection, and to his assistant, J. C. Kier, for much of the information regarding the manufacture and testing of these Krupp rails for the Boston & Maine R. R. These inspectors were sent abroad for the special purpose of handling this contract in co-operation with others already at the works, and that they conducted themselves and their work with a fidelity and zeal commensurate with the importance of the commission is a well recognized fact.

Ten Firms Produce 82 Per Cent of Total Output of Steel

Ten companies will control about 82 per cent of production in the steel industry on completion of pending mergers, and of these 10 the five largest will produce 41 of the 58,000,000-ton annual production of this country.

The ingot capacities of the 10 larger companies are as follows:

	Tons
United States Steel Corporation	23,046,000
Bethlehem Steel Corporation	7,900,000
Youngstown-Inland Corporation	5,040,000
Jones & Laughlin Steel Corporation	3,000,000
Republic-Trumbull Companies	1,950,000
American Rolling Mill Company	1,750,000
Central Alloy Steel Corporation	1,400,000
Wheeling Steel Corporation	1,273,000
Colorado Fuel and Iron Company	1,138,000
Corrigan, McKinney Steel Company	1,000,000
Total	47,497,000

Thirteen other steel companies, producing from 300,000 tons to 1,000,000 tons each yearly, provide most of the remainder of slightly less than 11,000,000 tons.

Advertisement Correction

On page 199 in the advertising section of the February issue of this magazine, the words "M-H Special" Chilled Bars appears as the heading to a paragraph. This heading should have read "M-H Special" Chilled Rolls.

Sheet Steel for Automobile Bodies

The Defects in Ingots — Influence of Chemical Composition — Soaking Pits and the Operation of Soaking—Blooming and the Effect of Ingot Temperature

"AUTOSHEET"

PART II

THE defects which are the cause of a surprisingly large number of rejects or "seconds" in the surface inspection of sheets are seams, scabs and blisters. Seams are the most common defect and are explainable, as follows: As previously mentioned the molten steel has absorbed large quantities of gases which are thrown out of the solution just before the steel crystallizes. As crystallization starts from a great many points or nuclei all of which are at a temperature for crystallization, the gases are trapped between the crystals and form elongated gas pockets or cavities, usually at right angles to the skin or wall of the ingot. As long as they are not exposed to any oxidizing atmosphere they will weld together when rolled into sheet bar. However a great many of the cavities exist close to the surface and once exposed, as upon reheating, are oxidized and when rolled do not weld together but produce seams which are very noticeable and objectionable in sheet steel for drawing purposes.

As mentioned in the teeming of ingots a splashing of the molten steel against the mold will cause scabs on the surface of the ingot which usually show up as slivers in the sheet bar. A rough mold will cause scabs. However, sheet manufacturers watch this closely, for good surface is necessary even on the ingots if a low percentage of rejected sheet is desired. The presence of blisters in a finished sheet may be due to excessive pickling of the sheet or to large inclusions of slag trapped in a way similar to the manner of the dissolved gases just described. As to the latter cause this can be eliminated in good open hearth practice. Ingot defects not readily detected in the visual inspection of sheet steel, are segregation, crystallization or ingotism and non-metallic inclusions.

Non-metallic inclusions or sonims are small pieces of refractory materials detached from the ladle or mold, small particles of entrapped slag as formed from the deoxidation of iron in the ladle and molds. These inclusions are usually very minute and distinguished only on a polished sample unetched by any acid. So small an amount of these sonims occur in good sheet steel that they are mentioned as a matter of information only.

However we do have inclusions which are distinguished after etching a polished portion of the steel and if occurring in sufficient quantities will impair the physical properties of the resulting sheet. There are two inclusions of this nature which are quite common and easily distinguished. The first is manganese sulphide MnS which due to its plasticity at the temperature that the steel is rolled presents an elongated shape, dove gray in color and parallel to the direction in which the steel is rolled. The second is iron silicate FeSi, which like MnS is plastic at the temperatures of rolling so that it also elongates itself parallel to the direction of rolling. It is distinguished from MnS in that it is decidedly darker upon etching. This latter inclusion causes less trouble than MnS and is often found imbedded within the sulphide.

Crystallization is the formation of large crystals of iron on slow cooling of the ingot and which will cause ingots to tear in rolling due to the lack of cohesion between the crystals at a high temperature. The greater the cooling surface of an ingot the more rapid the cool and consequently the smaller the size of the crystals of iron. It therefore is necessary to have the proper shaped mold and a low pouring temperature. As steel for sheets is reheated and rerolled and possibly annealed several times before completed, the large crystals from a slow cooling of the ingot are necessarily refined and this defect is included also as a matter of information only.

Segregation as we will speak of it is a detrimental collecting of phosphides and sulphides between the crystals of iron thus imparting a decided brittleness to the steel which is not removable upon reheating. Brittleness in sheet steel is a factor that must be eliminated if we want a ductile sheet. It frequently happens that an entire heat is affected by a brittle quality and a decision must be made regarding its use, for the manufacture of sheet involves high costs. Sometimes such a heat is shipped for some use in which it, being unfit, involves a loss of time, materials and even future orders. This is avoided by specifying certain chemical limits at the open hearth and by a sufficient cropping of the bar as we will now explain.

While the steel is in the molten state these impurities like the dissolved gases and inclusions mentioned above are entrapped by the iron crystallizing at a higher temperature. These sulphides and phosphides have a much lower melting point than iron and therefore that which is not trapped is literally squeezed from the solid solution and works its way toward the iron which remains still liquid, that is toward the top and center of the ingot. It is, therefore, natural to expect that the majority of the substances with low melting points would be found in one locality, as near the top and center of the ingot. This is found to be true and this segregation is called the "pipe" while the "line of segregation" extends through the center of the ingot which contains considerable amounts of entrapped impurities. This piping is cropped off at the shears on the bar mill and the depth to which it extends into the ingot is noted from the shear edge on the bar. If the shear blade drags the metal or otherwise throws a heavy burr not a sufficient length has been cropped. A clean sharp cut with little or no burr indicates the homogeneity of the metal and the absence of any segregated impurities in appreciable amounts.

Having taken the steel through its refining process as well as outlining some of the defects which occur in the formation of the ingots, we should consider the influence exerted by various metallic and nonmetallic elements and compounds as present in the resulting ingot and their effect on the final sheet. There are five important metallic elements to which we will give special attention as we know they are usually present in the finished sheet and are influential in its ductility. These are carbon, manganese, silicon, phosphorus and sulphur which are either alloyed with each other and with the contaminated metal or mechanically included.

Influence of Metallic Elements

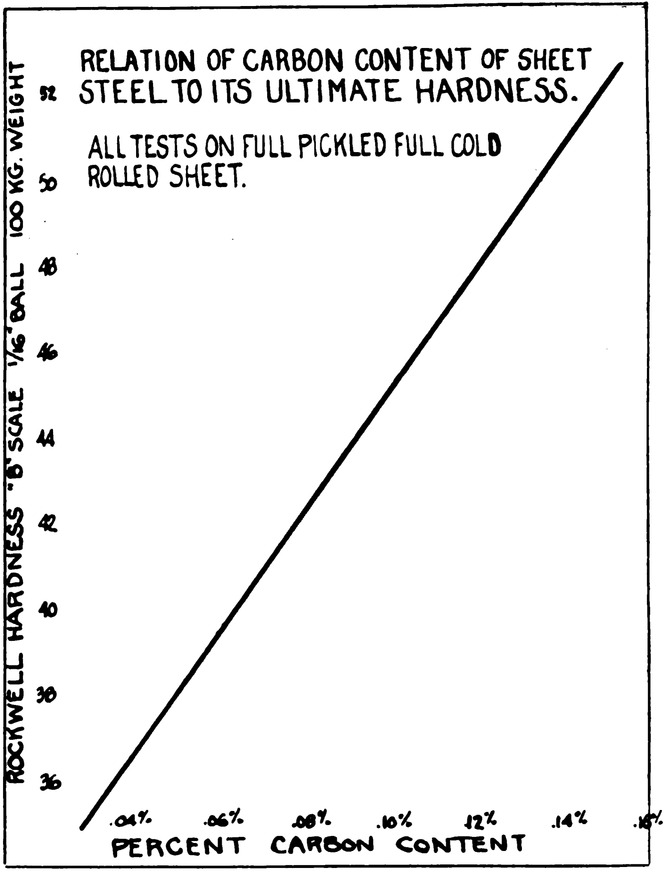
Carbon is the most influential element that we will consider in our sheet steels with a practical range of .05 to .15 per cent in the finished sheet with certain heats as low as .03 per cent. Carbon within this range of .03 to .15 per cent is so low that it immediately combines with iron to form iron carbide Fe_3C. This carbide is known as cementite and will be discussed to some length in another article. In the manufacture of sheet steels this carbon range is carefully watched as it not only influences the annealing ranges of the steel but is a definite factor in the resulting hardness of the sheet. To better illustrate this point we are including Graph I which relatively shows the carbon range of sheets and their corresponding hardness as determined on a Rockwell testing machine using a 1/16-in. test ball and a 100 kg. weight. In general it may be stated that within the carbon ranges as stated above the hardness will increase in proportion to the carbon present providing, of course, that the steels tested have all had the same treatment throughout the mill.

Manganese is present in our dead soft sheet steels in varying proportions, usually from .20 to .50 per cent. Manganese promotes soundness in the ingots by its deoxidizing effect on the liquid steel and gives a certain strength or body to the sheet, similar to carbon. Manganese readily combines with the small amounts of sulphur which are present as MnS (manganese sulphide). As mentioned above this appears as an elongated gray constituent parallel to the direction of rolling. It also combines with silicon to form MnSi (manganese silicate). Enough manganese is present to not only combine with the sulphur and silicon but an excess is usual which then combines with the carbon to form Mn_3C. This manganese carbide has practically the same molecular weight as Fe_3C and usually combines with it thus supporting our theory that like carbon it gives strength or body to the product.

As no metallographical test reveals cementite or Fe_3C free from manganese we must simply conclude that the cementite contains varying amounts of Mn_3C. Thus in steels having not less than .25 to .30 per cent manganese and not over .05 per cent sulphur we find the sulphur combined to form MnS and the remaining manganese forming Mn_3C and merging into the cementite. It has been stated by eminent authorities that increasing the manganese to over one per cent and decreasing the carbon content will increase the elastic limit and toughness of the steel but as we are not in the habit of making sheet steel having this manganese content we will not discuss this only to state that it helps to prove our contention that manganese gives strength to the sheet.

Sulphur is found in sheets from a trace to .04 or .05 per cent and in sheets made from bar cut close to the pipe of the ingot we can expect to find considerable more which is often the case. As mentioned before it has great affinity for manganese and in the event that the manganese does not absorb it as MnS it will combine with iron to form iron sulphide FeS which, like MnS, will have a lower melting point than the iron and consequently is trapped between the rapidly forming of iron crystals on cooling or go into the heavily segregated portion or pipe of the ingot.

GRAPH I



This FeS will, in sufficient quantities, form membranes or a network around the iron grains and being brittle in itself will allow little or no motion or slipping of these iron grains when the sheet is drawn which results in a sheet of low ductility and brittleness. While such cases as these are rare we will later reveal surprising examples of brittleness imparted by sulphides especially to sheets cut close to the pipe of the ingot.

Phosphorus in sheets will run from a trace to .04 or .05 per cent and most sheet makers keep it under .02 per cent as much as possible. It is usually held in solution as iron phosphide Fe_3P. While it does not in these proportions affect the physical properties of the sheet it may cause enlargement of the grains with subsequent brittleness. Phosphides like the sulphides have a tendency to segregate in the top of the ingot and often are trapped between crystallizing grains with the result that "ghost lines" appear. These ghost lines are indirectly the cause of our laminations in sheets and are so important that they will be discussed more in detail later. It is sufficient to say here that like sulphides they must be kept as low as possible as the subsequent reheating of the sheet will not alter the effect. It has often been said that phosphorus as high as .09 and .10 per cent present in

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TABLE II—Chemical Limits for Sheet Bar.

Element	Maximum	Minimum	Average	Desired	Use
Carbon	0.15%	0.05%	0.08%	0.10%	Full cold roll hood and fenders
	0.10%	0.05%	0.06%	0.07%	Extra deep draw body stampings
	0.10%	0.03%	0.04%	0.05%	Difficult body stampings
Manganese	0.50%	0.20%	0.45%	0.40%	Hood and fender stock
	0.40%	0.10%	0.25%	0.20%	Difficult body stampings
Sulphur	0.05%	0.005%	0.025%	nil	All body stampings
Phosphorus	0.05%	0.005%	0.015%	trace	All body stampings
	0.10%	0.005%	0.035%	0.025%	Furniture and hood stock
Silicon	0.008%	trace	trace	trace	All body stampings

sheets prevent sticking. It is the writers opinion that phosphorus to this extent may possibly prevent some sticking but its chief function is to promote a lustre desirable in furniture or fender sheets which are usually enameled. However for the purpose of lustre .05 to .07 per cent phosphorus should be sufficient.

Silicon is present in sheets only in traces up to .01 per cent and is found dissolved in the solution of iron as FeSi. It does not, within the limits named above, cause any marked effect on the structure or resulting physical properties of the sheet. It is known to promote soundness of the steel by forming SiO_2 thus lessening the tendency of forming blow holes.

Average Chemical Limits of a Heat

Having outlined the various impure elements present in sheets and their usual limits it would not be out of place to summarize the chemical limits of steel to be subsequently worked into sheet steels. While most manufacturers work to a low carbon range they differ in opinion as to the best proportion of manganese but agree on the limits of phosphorus, sulphur and silicon. Table II shows the average limits which, with reference to the above discussion, is self-explanatory.

The next step in the processing of sheet metal is the stripping of the molds from the solidified ingots which have sat in the pit anywhere from one to three hours after being teemed from the ladle. This solidifying period has cooled the steel to a point where all but the very center of the ingot has crystallized. The ingot, we will arbitrarily say, is 20 in. square at the bottom, tapering to 18 in. square at the top with an average height of 7 ft. This top to bottom taper of 2 in. facilitates easy stripping of the mold by special hooks on an overhead crane which fasten over lugs on the side of the mold. After stripping, the ingot is then sent to a reserve pile or "bank" or directly to the soaking pits to be reheated for rolling into sheet bars.

The Soaking Pits

The soaking pits vary in size and ingot capacity, but are essentially the same so far as their function is concerned. These pits are square or rectangular in shape and are lined with firebrick. The cover of this pit is of cast iron or riveted steel plate, the side exposed to the heat of the pit being laid in with firebrick. This cover fits the top of the pit in such a manner that by steam or hydraulic pressure the cover is made to slide or turn away from the mouth of the pit thus allowing the charging or discharging of ingots by an overhead crane.

If the heat for these pits is in the form of natural gas or coke oven gas the efficiency of the soak can be raised by regenerative heat chambers on each side of the pit which operate very similar to the regenerative chambers of an open hearth furnace previously explained. In this particular operation the gas and air enter through the right hand chamber and port and following its combustion the waste heat and gases pass through the opposite or left hand port and regenerative chamber and out through the stack. About every 10 or 15 minutes the air and gas are reversed which now pass through the opposite port and chamber thus completing the cycle. If fuel oil or powdered coal are used as the heat medium there is no necessity for regenerative chambers which, in the case of using powdered coal, would be quickly clogged by ash.

In soaking pits with regenerative chambers the ingot is charged in an upright position thus absorbing the heat through its outer surface or skin in the opposite manner from which the heat dissipated itself upon cooling in the mold. This manner of heating brings the ingot to the desired temperature quicker than if placed in any other position.

However, there are a few people who reheat their ingots in shallow furnaces, which hold about 10 ingots. This type of furnace is heated with powdered coal, gas or fuel oil through ports at both ends. In furnaces of this nature the ingots are charged from the side and lie flat thus exposing less surface for the reheat and causing at times the bottom side to be cold which may break the rolls used in reducing the ingot to bars. Furthermore if the ingot is direct from the pit and its center still in a semi-solid condition there is the possibility that the segregated impurities in the top of pipe of the ingot are shifted toward the center, due to the ingot lying on its side. This condition is very undesirable in sheets and necessitates a greater amount of crop or shearing to eliminate the impurities from the sheet bar.

Heating of Ingots

In bringing an ingot up to a temperature suitable for its reduction to sheet bar, our main consideration will be an even or through heating as quickly as possible without excessively scaling the ingot. Ingots for sheet bar being of low carbon content will have a final temperature before discharging of 2100 deg. F. to 2200 deg. F. As a general rule we may say that for hot ingots the length of time they will soak will be approximately the same length of time that they stood in the pits between their pouring and stripping. Thus if a hot ingot is charged into the soaking pit directly from the open hearth floor after having stood for one hour, before being stripped, we may say that this hour is the average time that the ingot will soak before being sent to the mills for rolling. In other words we are figuring that the heat dissipation from the mold and the absorbtion in the soaking will be approximately the same.

While this is the average soaking time we may attain the desired temperature in less time due to the fact that the melting point of our low carbon steels is so high that the possibilities of burning the steel are materially lessened. This factor allows us to drive the heat into the pit and bring the temperature up very quickly. Of course it must be kept in mind that the rate of heating must be such that a steady delivery of ingots to the rolling mill must be maintained. Too slow a heat will result in delivering the ingot under-heated which increases the power necessary to roll it out and decreases the length of time that it can be rolled before reheating. If not sufficiently plastic the last two or more passes in the mill may not shape the bar to the specified size which is a very important factor in the manufacture of sheet bar.

Too rapid a heat may cause the ingot to be overheated which will result in a growth of the grains of iron and a subsequent lack of cohesion between them which makes the metal too soft under the rolls. An uneven heating of the ingot presents more harmful results than either over or under heating. In the soaking pits in which the ingots are placed upright, care must be taken to heat one side of the ingot as much as the other as well as seeing that enough heat gets to the floor of the furnace. Uneven heating will cause one side of the ingot to get hotter than the other while a cold butt or end of an ingot may break the roll.

In furnaces of this nature there is less possibility of incorrect heating than in furnaces in which the ingot lies on its side. Such furnaces as the latter have no regenerative chambers and hence their efficiency is lower. As mentioned before they use fuel oil or powdered coal and the resulting flame can be regulated to strike the ingots if so desired. The ingots lie on their side and therefore a cold bottom side may result. A regulation of the length and intensity of the flame and where it will strike the ingots as well as a rapid reversal must be watched constantly.

Scaling and Burning

Regardless of the manner of soaking ingots the amount of scale on the ingot must be held low and very soft in order to be easily removed in rolling. If it is possible to gradually raise the heat of the furnace in proportion to the rise of heat in the ingot and to be able to give the ingot, in its last few minutes in the pit a good soaking heat, the resulting ingot will be low in scale and very soft.

Suppose that the ingots have been raised to the heat desired, the furnace dampered down and the high soaking heat that softens the scale has set in. For some unavoidable reason the ingots are held over and before discharging them reheat is again necessary. This reheating after the furnace has been dampered down brings a gas mixture usually rich in available oxygen which tends to raise another layer of scale on the ingot and as many times as this is done we will have as many layers of scale. The more scale the more difficult it is to get the center of the ingot hot and the more difficult it is to remove this scale during the reduction of the ingot by rolling.

As mentioned before the possibility of burning a low carbon steel is very slight for the lower the carbon content the higher the melting point. However the flame can be so concentrated on a portion of the ingots by the burners or failure to reverse often enough that the portions of ingots thus exposed to this high heat will cause the scale and possibly the skin of the ingot to run. The running of a thin skin will usually result in the exposure of the blow holes or gas pockets which become oxidized and subsequently form seams.

Having made the ingot plastic by reheating we are now ready to reduce it to a semi-finished product called sheet bar. This is first carried out on a large set of rolls, called a blooming mill and then into a sheet bar mill. To apply a specific example let us take an ingot 20 in. x 20 in. and carry it through these operations.

The Blooming Mill

The blooming, or cogging mills as they are called in England, are either two high of reversing or continuous drive or three high continuous. In our study of the making of sheet bar we will be interested only in the two high reversing bloom mill. Two high continuous blooms must have other mills along the line in tandem and while there are cases where this set up is used no mill making sheet bar exclusively has sufficient tonnage to keep such a set-up in continuous operation.

A two high reversing mill will have about 40-in. rolls to reduce this 20 in. x 20 in. ingot. It is generally supposed that this dimension means the diameter of the rolls or the distance between the center of one roll to the center of the other.

For an approximate dimension this is correct but it is better to consider this dimension as the distance between the center of one pinion to the center of the other pinion thus avoiding such variables as their constantly changed position to each other and their wear which, of course, affects their diameters and this specified size of 40 in.

Mills of this size usually work the ingot down to a size where the cross section is square and at least 6 in. on a side. Any section reduced on these mills to this size or over is called a "bloom" while if further reduced on other mills to a size ranging from 1½ to 6 in., round or square, it is called a "billet." In the event that the cross section is rectangular in shape and the width exceeds by far the thickness, such as 3 in. x 4 in., it would be called a "slab." "Sheet bar" will have a thickness less than 2 in. and a width ranging from 6 to 12 in. Blooms, billets, slab and sheet bar have rounded edges, are not usually straightened or cut square at the ends and are only adapted for further reduction and working into more highly finished products, hence their general classification of semi-finished products.

Referring back to the rolling of our 20 in. x 20 in. ingot through the two high reversing blooming mill we bring the ingot from the soaking pits, carrying an even heat of about 2100 to 2200 deg. F. By reversing the screw or draught on the ingot as it passes between the various grooves on the rolls we gradually reduce its cross-sectional area meanwhile continually elongating the ingot. Sketch No. 1 Fig. 1 shows the general shape of one of the rolls, the other roll having a corresponding shape and in line with that illustrated. In the first pass through groove No. 1 the reduction is heavy on one side and the ingot is usually run back through the same groove under a slightly heavier draught which usually remains "set" for the remainder of the rolling of the bloom barring rolling complications which may arise but which we shall not discuss here.

At the end of the second pass through the same groove the ingot is down to approximately 20½ in. x 17 in. and is then turned on the runout table, by steel

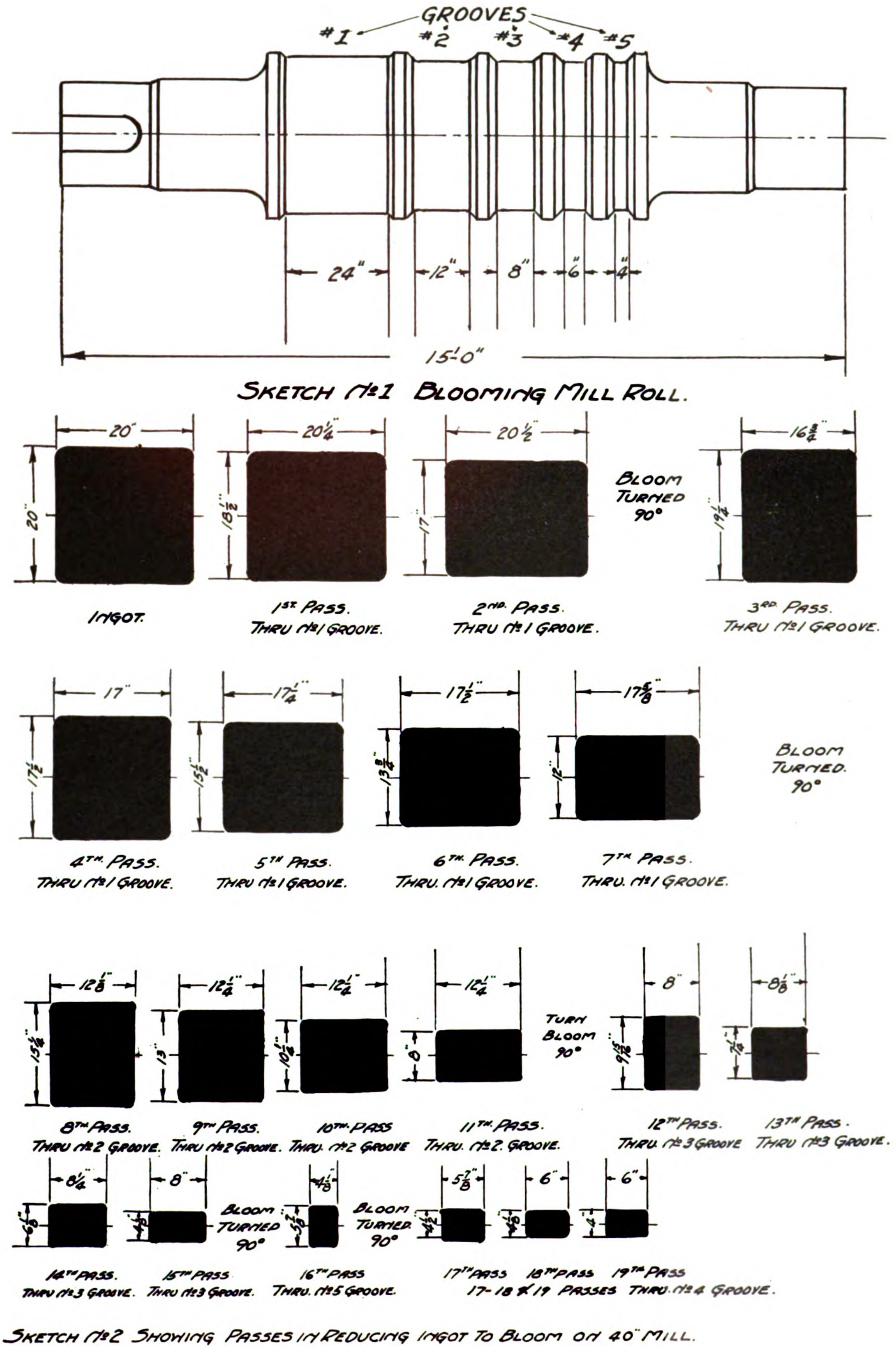

FIG. 1—Blooming mill roll and passes—40-in. mill.

fingers or manipulators, quarter way over. By this turning we place the ingot on its edge which allows the next few passes in the second groove to iron out the fins or ridges formed by a squeezing of the excess metal between the rolls of the previous pass. This rotating is done just before the ingot goes into a smaller groove for its first pass in that groove.

By rotating this ingot or, in other words, giving it alternate flat and edging passing and at the same time passing it back and forth between the rolls, we gradually reduce it to a 4 in. x 6 in. bloom. The number of passes will vary with the size, temperature and composition of the ingot but using a low carbon ingot, uniformly heated and 20 in. x 20 in. at the start, about 19 passes are necessary. To illustrate this, sketch No. 2 Fig. 1 shows the various cross-sections of the ingot under its various passes.

During these reductions we have been removing the scale adhering to the skin of the ingot by spraying it with water, under hydraulic pressure. As this water hits the ingot a foot or two away from the rolls, it has no chance to escape but is drawn in between the rolls and the hot metal. This naturally tends to gasify the water and the resulting gas seeking to escape gets under the scale thus lifting it from the ingot. The effect of scale rolled into the bar or even adhering too long during the reduction of the ingot, will be discussed shortly under the surface defects encountered from bloom and sheet bar mills.

Effect of Ingot Temperature on Rolling

Before leaving our description of the rolling of blooms it might be well to mention the effect of varying heats in the soaking pits on the rolls and on the rolling of the bloom. While we have said that the draught of the mill remains unchanged for the entire rolling this is true only when ideal conditions, such as uniformly heated ingots, are present. If heated in a soaking pit where the ingots lay on their sides we might have a cold side in the rolls. This cold side shows a marked tendency to curl up at the ends and if a cold side is present this is kept against the under side or bottom roll going through in order to keep the ingot as flat as possible.

If the ingots are soaked in an upright position the bottom end might be too cold which, under certain conditions of draught and the heat in the remainder of the ingot, might crack the rolls. Uneven heating of the ingot may cause more pressure on one roll than the other which is very undesirable, while an overheated ingot allows greater draught and requires less passes to finish.

(To be continued)

Gas Flow in Open Hearth Furnaces*

Abstract of Studies Made on the Flow of Gas and Gas Compositions in Various Types of Open-Hearth Furnaces—Conditions of Combustion and Location of Flame

Translated by K. FELLER†

THE flow of gas and air in an open hearth furnace is of decisive importance for preheating, conditions of combustion, and heat transfer in the furnace proper. The three papers on which a summarized report is given hereafter treat on this subject:

The first paper of S. Schleicher and Fr. Lueth dwells upon the conditions of combustion in the hearth area, whereas the second paper by S. Schleicher treats the movement of gas in the chambers. The third by G. Neumann may, in some respects, be looked upon as an investigation supplementing the other two.

Schleicher and Lueth, the same as Neumann, have used water-cooled tubes for their investigations of the character of gases in the hearth area in order to obtain the desired information on the progress of combustion and the characteristics of the flame. The results are shown in diagrams as given under Fig. 1, by lines of equal contents oxygen, carbonic-acid and combustible components. For the investigations these were selected:

Two furnaces of standard design with double and single gas and air ports;

Two tilting furnaces with one gas and one air port of which the one was well, the other badly adjusted;

One Maerz-furnace of standard and one of somewhat modified design;

One Moll-furnace.

The common features of all these designs are:

1—The flame consists of a burning envelope, the interior of which is filled with unburned gas, whereas the other portion of the furnace—at least on the first third on the side of the intake port—is taken up by air and with a content of carbonic acid increasing towards the outlet side. A better mixing takes place only towards the center of the furnace, where, in case of well adjusted furnaces, the flame starts to break up. An absolutely uniform composition of gas or products of combustion respectively is not arrived at, not even in the vicinity of the outlet port.

2—The forcing back towards the back wall of the flame or of a flow which still contains some per cent of unburned components is also a common feature of all the furnaces examined. Schleicher and Lueth attribute this to the leakage of air through the doors. Neumann suspects this to be due to a spiral gas flow, originating from a quicker rising of gas along the warmer backwall.

3—From the investigations of Schleicher and Lueth follows, that also in case of ports reduced in length from ordinary wear—provided, of course, that the gas and air inlets are kept in good condition—a good flow of gas can be kept up to a far greater degree than heretofore assumed. This coincides with experience in practice, which indicates aggravating conditions usually only in case of the

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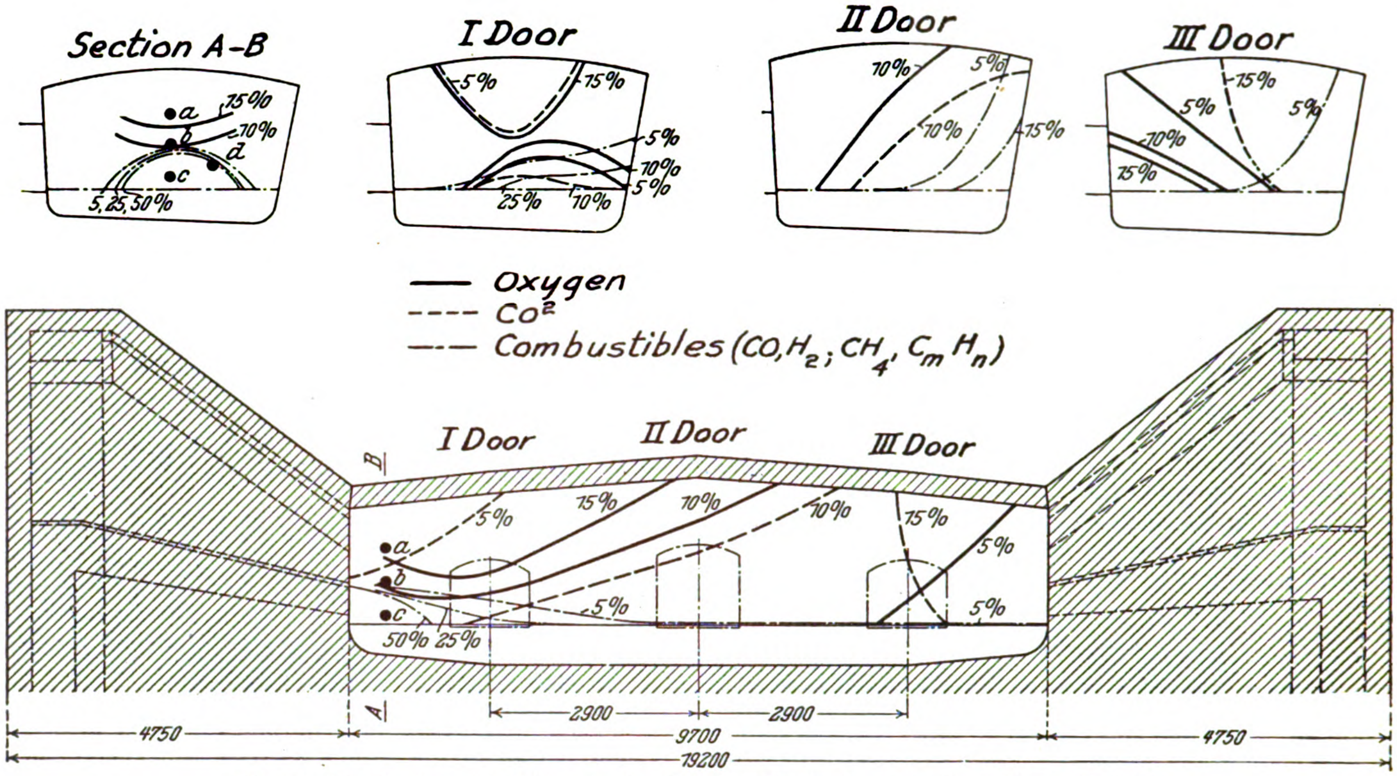

FIG. 1—Combustion conditions in the Siemens-Martin furnace of usual construction.

ports being reduced in length to such an extent that the breaking up of the gas stream commences at the first door.

The characteristics of the furnaces of different design and different adjustment are readily distinguished. The furnace of ordinary design, having two gas and two air inlets is marked by a shorter flame than in case of a furnace having one gas and one air inlet. This confirms the manifold expressed opinion that the design providing two inlets is more suitable for comparatively wide and short hearths, whereas long and narrow hearths should be suitably provided with one gas inlet. The design having two gas and one big air inlet, which transfers the entire control solely to the gas stream, unfortunately has not yet been available for comparisons. In the examined furnaces the air of combustion had, however, so much energy that it pressed the flame down on the metal.

Tilting Furnace

The tilting furnace with good adjustment examined by Schleicher and Lueth had comparatively close fitting doors; whereas it shows distinctly a pushing back of the flame as a result of leakage of air at the joints was due to wind blowing accidentally against the front of the furnace at the time of observation. This shows how valuable it can be to protect charging platforms against bad weather conditions. As for the rest, the conditions prevailing at this furnace strongly support the opinion that the pushing back of the flame is caused by inleaking air; for the fairly considerable differences at the incoming port, indicated by the tests, disappear in the neighborhood of the stack-head. At the same time, the supposition is confirmed that doors set sufficiently inclined provide in practice sufficient protection against inleaking air.

The tilting furnace examined by Neumann may be looked upon as a characteristic example of unsuitable adjustment under poor gas conditions. The partial receding of the flame into the air inlet points to an excess of gas. Contrary to the investigations of Schleicher and Lueth, Neumann points out especially the irregularity of the composition of gas at the test points. Observations of this nature could not be made clearly by Schleicher and Lueth. Undoubtedly, this irregularity is due to the absence of a suitable gas pressure control, and it shows distinctly how disadvantageous working under such conditions is. The simultaneous presence of 2 per cent oxygen and a considerable excess of gas is remarkable inasmuch as it shows, in spite of the considerably higher temperatures, similar conditions as one may find occasionally in other furnaces working with insufficiency of air, in which, however, the temperature of products of combustion has fallen below the so-called ignition temperature. The two furnaces designed by Maerz, mentioned in the first named paper, compare principally two different furnace adjustments; the comparison appears not to be clear, owing to simultaneous though apparently, unimportant alteration of the Maerz ports. The nature of this alteration consisted to some measure in a horizontal guiding of the air by reconditioning the port. The pushing back of the flame to the backwall is considerably reduced in this device. The Maerz furnace of unaltered design was worked during the trials with an exceptional high draught, and the fact that the disturbances in the development of the flame at the discharge port, due to high draught, resulted in 6½ per cent unburned fuel in the hearth area in the vicinity of the backwall only, certainly speaks for this design, especially, if one considers that operators, when handling furnaces having disturbances in their air supply, often open the damper in order to replace the missing air of combustion by atmospheric air.

The Moll-furnace examined is marked by its extraordinary short flame at a comparatively great sur-

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plus of air, at least, if one follows the quantity of combustible contents and oxygen along the path of the flame. The steady increase of carbonic-acid, however, contradicts this, especially as the oxygen lines point to a fairly strong inleakage of air through the doors.

Experiments on Models

The examinations of the conditions of flow in the chambers by means of trials on models were used by Schleicher for a special paper. It is important in repeating such trials to be careful with models as to dimensions and speed of flow. In order to arrive at correct conclusions, the speed of flow was varied considerably in the chamber model used, without finding appreciable differences in the results. This alone would not be sufficient to prove the similarity as one occasionally finds critical figures in the vicinity of which the conditions alter by leaps. But that the proportions were chosen correctly in the case under consideration is proven by the fact that the results obtained from the model trials were successfully adopted to actual practice. Schleicher found with his model that the efficiency of the chambers was only 50 per cent. Consequently, those parts of the checker work which supposedly did not take part in the heat exchange were dismantled and replaced by simple ascending and descending flues. When the furnace was again put in operation, it showed no difference in the rate of melting. Attempt was made to clearly define the effect of these flues by the pyrometer, but the rises in temperature, as far as they were obtained by ordinary thermo-couples, appeared to be too high on account of the radiating heat of the hotter walls. Measurements with the ordinary pyrometer showed lower figures, and we can assume that still lower figures would be obtained with pyrometers designed by Wenzl and Schulze.

The first of the models examined by Schleicher is a chamber with a built-in slag pocket and vertical gas uptakes above it. Later the chamber was arranged with a slag pocket positioned in front and the investigation repeated. Also, with this arrangement the model showed decidedly an incomplete utilization of the chamber. It is said, however, that this observation does not coincide with others made in practice. The paper by Neumann may in this point be regarded as being supplementary to that of Schleicher. The reasoning of Neumann is based upon the assumption that restricting the heat exchange to only a part of the chamber should manifest itself in marked differences of temperature when measuring the temperatures of checkers in different parts of a horizontal section. He found, however, from his investigations of the tilting furnace in the fairly long air chamber at a mean temperature of the checker surface of 1100 deg. C., that during the air period the portion of checker work closest to the slag pocket was not more than 135 deg. C. cooler than on the outlet side. In the gas period this difference was found to be only 80 deg. C. The conclusion drawn from the experiments with this furnace—that nearly the whole of the checker work takes part in the heat exchange in an approximately uniform manner—coincides with observations of others made during the heating up of furnaces.

Of particular interest are the investigations of Neumann concerning changes of composition of gas on its way through the furnace. The furnace examined was heated with lignite producer gas, having a content of tar, 50 to 80 grams per cubic meter; water, 210 to 250 grams per cubic meter.

The average alteration of the gas composition is shown in the following list:

Gas composition	CO %	H_2 %	CO_2 %	CH_4 %	C_nH_m %
In the port	26	22	6.5	3.7	0.3
In the gas line	30	15	4.25	3.1	0.3

As a result of the temperature-variations during the gas period, also the composition of gas in the port alters as a function of the preheating temperature. The figures shown in the different diagrams coincide with the characteristic curve of the temperature-drop which falls at the commencement of the ingoing period considerably faster than towards the end of this period. The kind of disintegration shows clearly the influence of the equilibrium of water-gas in presence of sud originating from tar. In spite of the measured temperature of 1100 deg. C. the gas preheating does not seem to attain such a temperature that the equilibrium of water-gas can slide into the area of carbon monoxide.

Meeting of American Institute of Mining and Metallurgical Engineers

Iron and steel was much to the fore at the annual meeting of the American Institute of Mining and Metallurgical Engineers, held on February 20 to 23, at the institute headquarters, 29 West 39th Street, N. Y. On Monday morning, February 20, Prof. William Campbell presided over a session, at 10 A. M., at which a number of important papers on ferrous metallurgy were discussed. A. B. Kinzel presented a paper on chromium iron alloys, which is a valuable contribution to knowledge of the subject, involving a decidedly advanced technique and high order of accuracy, and describes a new type of furnace which may find a variety of applications in the future.

The afternoon session on February 20 was devoted to papers on the commercial aspects of steel manufacture at which Dr. J. A. Mathews presided. Robert Job discussed the types of steel used by railroads, past and present, and C. W. Gennet described the manufacture of some foreign rails. E. A. Richardson of the Bethlehem Steel Company presented a paper on aircraft steel, and Lloyd Jones of the E. W. Bliss Company, described the continuous rolling of sheets.

On the afternoon of February 21 the open hearth was the topic of discussion, with L. F. Reinartz presiding. C. E. Meissner described the 1-ton acid open hearth furnace constructed at the Chrome Steel works, and the results obtained in its operation. A. L. Field discussed the rate of carbon elimination and degree of oxidation in acid open hearth practice. C. H. Herty and J. M. Gaines presented the results of their study of the effect of temperature on the solubility of oxygen in iron.

Wednesday morning was devoted to the blast furnace, with R. H. Sweetser presiding. J. P. Dovel related what he had done to make the blast furnace a permanent structure instead of one that has to be periodically rebuilt, at a cost that eats up most of the profits of its operation. W. R. Phibbs talked on the interesting special features in the operation of the blast furnace at Ironton, Utah.

*The Solubility of Iron Oxide in Iron**

Effect of Temperature Under Iron Oxide and Lime Iron Oxide Slags for Pure Iron — Distribution Ratio Between Slag and Metal and Relation to Open-Hearth Operations

By C. H. HERTY, Jr.† and J. M. GAINES, Jr.‡

IRON oxide (FeO) plays an extremely important part in the manufacture of steel. In the open-hearth furnace and the Bessemer converter it is the chemically predominant compound and controls to a large extent both the operation of the furnaces and the composition and quality of their products. Almost all of the refining action is carried out through the medium of FeO, which oxidizes carbon, manganese, silicon, and phosphorus.

At the end of any open-hearth or Bessemer heat the steel contains dissolved iron oxide, which must be wholly or partly eliminated. The type of deoxidation product depends on the amount of dissolved iron oxide and on the deoxidizer used. After the heat has been deoxidized and while it is being teemed, iron oxide diffuses from the ladle slag into the metal, causing losses of deoxidizer and increase in iron oxide content of the steel.

It is generally believed that non-metallic inclusions are responsible for a great many failures of steel in service and for decreased yield of steel during rolling. The basis of most non-metallic inclusions is dissolved iron oxide.

This investigation was undertaken in order to determine the amount of iron oxide that will dissolve in iron under various conditions. Steelmaking slags are complex and it has been thought best to determine solubility under simple slags as a first step. The study is being continued under slags whose compositions approach those of operating slags.

Previous Investigations

The solubility of oxygen in iron has been determined by a number of investigators (see Table 1), but their efforts have been directed toward the solubility at the melting point of iron, 1535 deg. C. In the determination reported by the Bureau of Standards, a number of values for oxygen in iron, ranging from 0.24 to 0.28, are given. These, however, were determined after the metal had been exposed to an oxidizing flame in addition to simple melting. It is very probable that the reason for these higher values is that the metal was considerably above its melting point. It should be noted here that de Coussergues¶ quotes Eichoff as giving a curve for the solubility of iron oxide in iron against temperature. On referring to the original article,§ however, it is found that Eichoff assumed the solubility curve and that no determinations were made.

From the results just given it is very evident that the solubility at the melting point may be called 0.21 per cent oxygen, inasmuch as all investigators agree on this point. Unfortunately, none of the higher values have corresponding temperature figures, so they must be thrown out as far as quantitative discussion is concerned.

TABLE I

Solubility of Oxygen in Iron at Its Melting Point.

Investigator	Oxygen %	Remarks	Reference
Austen	0.280	No temperatures given.	Jnl. Iron and Steel Inst. (1915) 92, 157.
U. S. Bureau of Standards	0.21	At melting point.	Chem. & Met. Eng. (1922) 26, 778.
Tritton and Hanson	0.21	At melting point.	Jnl. Iron and Steel Inst. (1924) 109, 90.
Herty	0.27	Above melting point.	Trans. (1926) 73. 1107.
Herty	0.22	At melting point.	Op. cit.

Experimental Method

In making determinations on the solubility of iron oxide in iron, a 50-kw. Ajax-Northrup furnace was used. This was equipped with a magnesia-lined graphite crucible in which 50 lb. of electrolytic iron was melted and held at the required temperature. When the metal was melted, the desired slag—either iron oxide or a mixture of lime and iron oxide—was added in sufficient quantity to give a liquid ring on the surface of the metal. Temperature readings were taken at frequent intervals and when the temperature had been constant for 15 min., samples of slag and metal were taken. The slag was analyzed by the usual laboratory methods for FeO, Fe_2O_3, SiO_2, MgO, and CaO. One or two samples of metal from each heat were analyzed for the usual constituents, carbon, manganese, phosphorus, etc, and all samples were run by the modified Ledebur method for oxygen content.

From the slag analysis the mol per cent of FeO in the slag was calculated. This value, together with the determined quantity of oxygen in the metal in equilibrium with this slag, enabled calculation of the distribution of iron oxide between slag and metal by the ratio

$$\frac{\text{mol per cent FeO in the slag}}{\text{per cent oxygen in the metal}}.$$

From the distribution ratio a value for the solubility under a slag of 100 mol per cent FeO was determined, and this value plotted against observed temperature was used in preparing the solubility curve.

Sampling—Samples of metal from the melt were taken with a steel spoon. An attempt was made to coat this spoon with magnesia, but it was found that

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*Paper presented at the February meeting of the American Institute of Mining and Metallurgical Engineers, New York City.

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¶C. de Coussergues: Influence of Temperature in the Manufacture of Steel. Revue de Metallurgie, Mem. (1922) 19, 641.

§Eichoff: Advance in Electric Steel. Stahl und Eisen (1907) 27, 48.

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the sudden heating caused the magnesia to crack off almost at once. For this reason, fireclay coating was used on the spoon, even though a small amount of silica was introduced into the slag thereby.

The action of the current in the furnace causes a violent boil of the metal, which results in very intimate contact at the slag-metal surface and throws slag into a ring around the top of the metal surface. On account of this, the question arose as to whether or not any slag was entrapped in the metal during the boiling. In order to determine whether or not this was so, samples were taken with power on, then the power was shut off and another sample was taken 1.5 min. later. These showed no appeciable difference in oxygen content, indicating that the samples with the power did not contain entrapped slag (see Table 2). This conclusion was verified by making an analysis for lime in metal samples taken under lime-iron oxide slags. No traces of lime could be detected in these samples. It will be noted that very close checks were obtained between all samples except No. 9 and 10, and this discrepancy is probably due to other causes.

In the first heat, metal samples were poured into an ordinary test mold such as is used in open-hearth shops. After the first two or three samples, when the metal became fairly high in oxygen, it was apparent that some of the iron oxide was coming to the surface on account of the slow cooling of the relatively large mass of sample. For the last two samples on this heat (No. B) the mold was cooled with water, which effectively entrapped all of the dissolved iron oxide. On subsequent heats a special mold was used, consisting of a thin wedge cut in a rather large block of steel. This provided a heat reservoir which chilled the metal almost instantaneously and insured very good sampling conditions. Samples of slag were taken by shutting off the power momentarily and dipping a cold spoon into the surface of the slag. The slag chilled on the spoon and was then knocked off and preserved for analysis.

TABLE II
Effect of Boiling of Metal on Slag Inclusion.

Sample No.	Boiling	Sample No.	Quiet
7	0.224	8	0.225
9	0.318	10	0.238
11	0.208	12	0.207
13	0.197	14	0.186
15	0.225	16	0.233
17	0.220	18	0.222
19	0.199	20	0.199
21	0.269	22	0.260

Measurement of Temperature—The temperature of the metal in all heats was measured with a Leeds & Northrup optical pyrometer. Because the metal in the crucible was neither under black-body conditions nor free-radiating, a correction for emissivity had to be determined and applied. This was done by using a bath of pig iron in which a silica tube protected by a graphite casing could be immersed. Temperatures were read both on the free surface and on the bottom of the closed tube and the differences noted. Table 3 shows the comparison between the true temperature and the observed temperature, obtained by sighting on the metal surface.

All the temperatures recorded in the experimental heats were corrected by these data, except heat EE, in which advantage was taken of the fact that the slag formed an overhanging ring above the metal surface and it was possible to sight underneath this ring where conditions closely approximating black-body conditions prevailed. With the metal just at the melting point on the occasions mentioned, the correction was found to be 1.01 and this factor was used in determining true temperatures on heat EE.

TABLE III
True Temperature Measurements

(1) Observed Temperature	(2) True Temperature	Ratio (2/1)
1300	1394	1.072
1350	1449	1.072
1400	1504	1.073
1450	1566	1.080
1500	1630	1.087
1550	1697	1.093

Explanation of Units Used

Mol Per Cent FeO in the Slag—In determining the activity of a substance in solution it is necessary to know its concentration in terms of molecules instead of weight units. The molecular per cent of a substance in solution is the number of molecules of the substance divided by the total number of molecules present, and is commonly termed "mol per cent." The relative number of molecules of two or more substances in solution is obtained by dividing the weight per cent of each by its molecular weight. The mol per cent of any one is then easily determined. For example: consider a slag analyzing 50 per cent FeO, 40 per cent CaO, and 10 per cent MgO: The relative molecular concentrations are:

$$\mathrm{FeO} = \frac{50}{71.85} = 0.696$$

$$\mathrm{CaO} = \frac{40}{56.0} = 0.715$$

$$\mathrm{MgO} = \frac{10}{40.3} = 0.248$$

The total mols are equal to the sum of the three $= 0.696 + 0.715 + 0.248 = 1.659$ and the "mol percentages" are:

$$\mathrm{FeO} = \frac{0.696}{1.659} = 42.0 \text{ per cent}$$

$$\mathrm{CaO} = \frac{0.715}{1.659} = 43.1 \text{ per cent}$$

$$\mathrm{MgO} = \frac{0.248}{1.659} = 14.9 \text{ per cent}$$

If definite compounds of two or more substances exist in the liquid slag they must be taken into account as compounds and not as mixed oxides in calculating mol per cent of any component of the slag.

Correction for Fe_2O_3 in the Slag—Fe_2O_3 present in the slag is considered as being reduced to FeO at the slag-metal surface by the reaction

$$Fe_2O_3 + Fe \leftrightarrows 3FeO.$$

All slags have been corrected for Fe_2O_3 by this equation.*

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*C. H. Herty, Jr.: Chemical Equilibrium of Manganese, Carbon, and Phosphorus in the Basic Open-hearth Process. Trans. (1926) 73, 1107.

Results

Fig. 1 shows the distribution ratio

$$\frac{\text{mol per cent FeO in the slag}}{\text{weight per cent FeO in the metal}}$$

plotted against temperature. Fig. 2 shows the solubility curve, obtained from Fig. 1 by the relation

$$\text{Solubility of FeO} = \frac{100}{\text{the distribution ratio}}.$$

At 1600 deg. C., the normal open-hearth tapping temperature, the solubility of FeO in iron is 1.36 per cent FeO (0.304 per cent O_2). At 1700 deg. C. the solubility increases to 2.02 per cent FeO (0.452 per cent O_2).

Table 4 gives the essential data on FeO on all heats made. Table 5 gives typical metal and slag analyses. In general, the magnesia crucibles held up well under the action of the slag.

TABLE IV
Results of Solubility Determinations.

Sample No.*	Temperature deg. C.	Mol. per cent FeO in slag (1)	Per cent FeO in metal (2)	Distribution ratio = (1)/(2) = (3)	Solubility per cent FeO
B-7	1734	91.8	2.28	40.2	2.48
D-9	1703	84.0	1.73	48.4	2.02
D-8	1691	88.5	1.75	50.4	1.97
BB-17, 18	1685	50.5	0.99	51.1	1.96
BB-19, 20	1685	49.0	0.89	54.8	1.82
EE-11	1685	56.0	1.09	51.5	1.94
D-7	1675	90.8	1.35	66.8	1.49
BB-9, 10	1670	63.3	1.07	59.4	1.68
BB-11, 12	1667	53.0	0.96	55.5	1.80
D-2	1653	99.8	1.92	51.7	1.92
D-1	1653	99.8	1.67	59.5	1.67
D-6	1652	92.4	1.54	59.5	1.67
BB-7, 8	1648	63.5	1.01	63.2	1.58
BB-13, 14	1638	51.2	0.86	59.5	1.68
E-9	1621	88.2	1.30	67.7	1.47
EE-10	1615	64.5	0.88	73.4	1.36
EE-2	1610	86.9	1.15	75.6	1.32
B-9	1609	91.8	1.39	65.1	1.51
D-4	1606	97.6	1.35	72.5	1.38
E-8	1606	89.5	1.28	69.8	1.43
EE-1	1605	90.9	1.25	73.0	1.37
EE-3	1605	84.8	1.15	73.8	1.35
EE-6	1605	73.5	1.16	63.4	1.58
EE-7	1605	73.7	1.05	70.0	1.43
EE-8	1605	73.4	1.08	68.3	1.46
EE-5	1600	77.5	1.25	62.3	1.61
EE-9	1600	71.3	0.89	80.5	1.24
BB-5, 6	1598	72.8	1.04	70.3	1.42
E- 7	1565	96.0	1.04	94.2	1.06
E-4	1564	96.0	1.12	86.0	1.17
E-1	1550	96.0	1.19	80.6	1.24
E-2	1540	96.0	1.15	84.0	1.19
E-5	1540	96.0	1.24	77.2	1.30
BB-1	1535	100.0	1.06	94.2	1.05

*Single letters refer to heats with iron oxide slags; double letters to heats with lime-iron oxide slags.

TABLE V
Typical Slag and Metal Analyses

From Experimental Heats under Iron Oxide Slags

METAL

Component	B, per cent	D, per cent	E, per cent
C	0.007	0.011	0.009
Mn	None	None	
P	0.006	0.005	0.007
Si	0.007	......	0.003
S	0.019	0.016	0.011

SLAG

FeO	.....	75.0	83.3
Fe_2O_3	.....	15.0	12.5
SiO_2	.....	2.20	1.70
CaO	.....	None	None
MgO	.....	6.80	3.2
S	.....	0.074	......

From Experimental Heats under Lime-iron Oxide Slags

METAL

Component	BB, per cent	EE, per cent
C	0.003	0.006
Mn	None	None
P	0.004	.....
Si	0.004	.....
S	0.018	0.016

SLAG

	First slag	Last slag	First slag	Last slag
FeO	58.50	33.90	76.50	38.90
Fe_2O_3	18.70	21.20	14.20	21.30
CaO	14.85	25.15	0.74	32.80
MgO	7.75	20.65	4.74	6.66
SiO_2	1.60	1.00	2.30	1.88

Discussion of Results

Solubility Curve—It will be noted that at temperatures just above the melting point the per cent FeO in the metal is somewhat higher than the straight-line given in Fig. 2. At these low temperatures it was almost impossible to effect a clean separation of slag and metal, as a large part of the sample would freeze in the sampling spoon. As the temperature was raised, a good separation was obtained and perfectly clean samples resulted. A few points at 1,540 deg. C. were so very high in iron oxide, on account of trapped slag, that they have been omitted in Fig. 2 and Table 4. The straight-line relationship between temperature and FeO content of the metal has been drawn neglecting the four determinations at temperatures just above the melting point.

Form in Which Oxygen is Dissolved in the Metal—The fact that increasing amounts of oxygen are found in the metal with increasing temperature indicates that oxygen dissolved in the metal is present as a compound and not as a gas. Gas dissolved in liquids shows decreasing solubility with increasing temperature. Knowledge of the compound formed may be obtained from a consideration of the distribution ratios given in Table 4. Nernst,* from theoretical considerations and experimental evidence, formulated the law of distribution which may be summarized as follows: If a substance be dissolved in two immiscible or slightly miscible liquids (in this case slag and metal), it possesses a constant distribution coefficient at a given temperature when it exists as the same molecular species in both solvents. Table 6 gives the distribution ratios observed over the temperature range 1,598 deg. to 1,615 deg. C. The distribution ratio is constant over a wide range in mol per cent FeO in the slag, the average per cent deviation in distribution being 5.45 per cent. This shows that the oxygen in the metal is present as FeO.

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*W. Nernst: Distribution of a Substance Between Two Solvents and Between Solvent and Gas. Zeitschr. phys. Chem. (1891 8, 110.

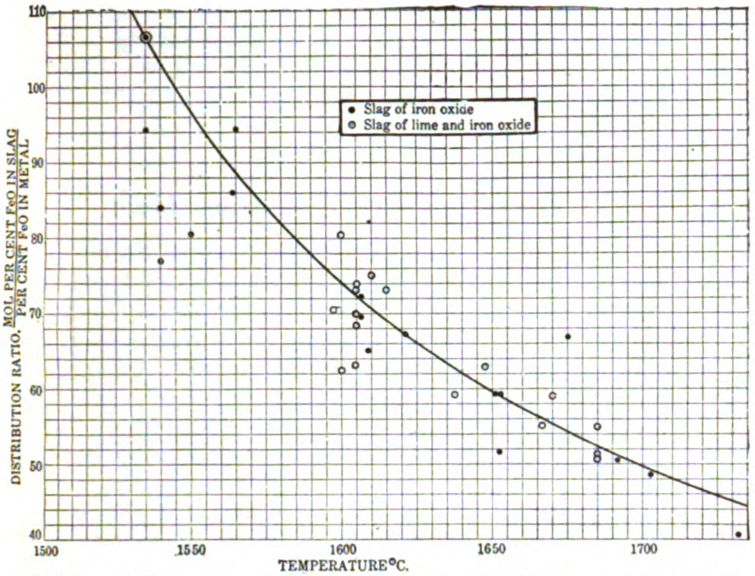

FIG. 1—Effect of temperature on the distribution of iron oxide between slag and metal.

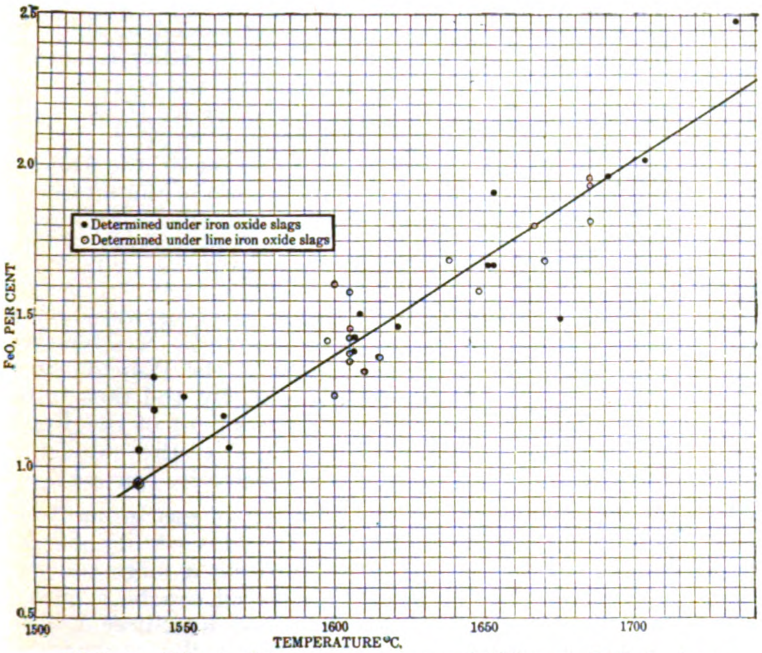

FIG. 2—Effect of temperature on solubility of FeO in iron.

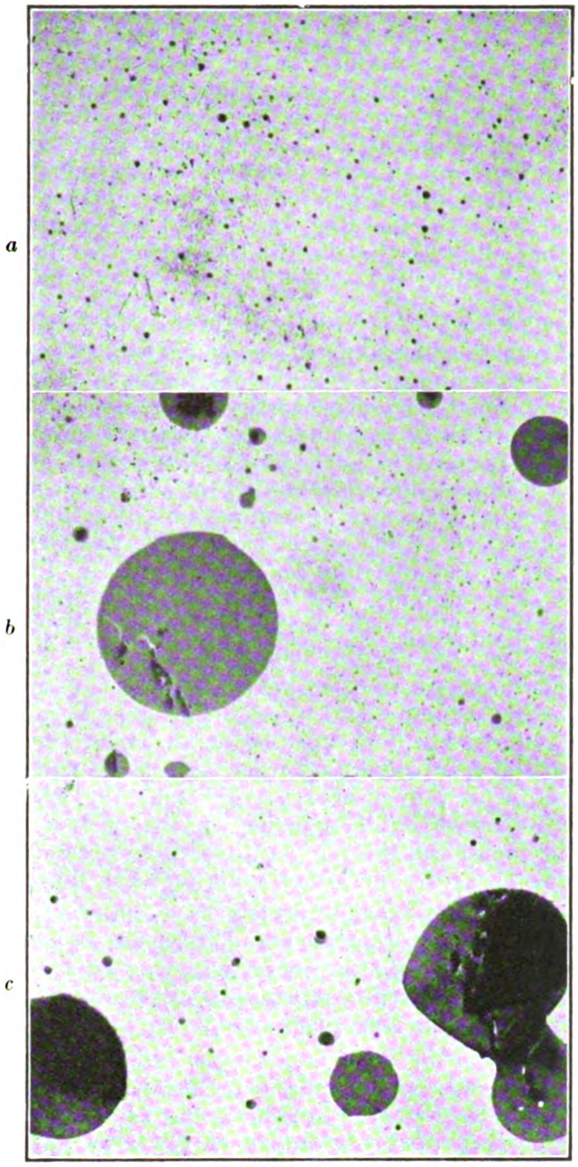

FIG. 3—Inclusions in iron-oxygen alloys. a, FeO = 0.90 per cent; b, FeO = 1.75 per cent; c, FeO = 2.46 per cent. (Section taken from top of slowly cooled ingot, showing particles in process of coalescence.)

Dissociation of Compound in Liquid Slags—All the slags contained considerable amounts of Fe_2O_3, because of oxidation of the slag by the gases over the melt. The lime-iron oxide slags contained about 5 per cent more Fe_2O_3 than the slags without lime. This was due either to the formation of calcium ferrate or to slower diffusion of Fe_2O_3 to the slag-metal surface, the lime-iron oxide slags being somewhat more viscous than the slags containing only iron oxide. The fact that the distribution ratio,

$$\frac{\text{mol per cent FeO in slag}}{\text{weight per cent FeO in the metal}},$$

was the same for both iron oxide and lime-iron oxide slags at a given temperature shows that if any compound, such as calcium ferrate, was formed, it was dissociated at the slag-metal surface.

TABLE VI
Constancy of Distribution Ratio with Varying Mol Per Cent FeO in the Slag.

Sample	Temperature deg. C	Mol. per cent FeO	Distribution ratio
D-4	1606	97.6	72.5
B-9	1609	91.8	65.1
EE-1	1605	90.9	73.0
E-8	1606	89.5	69.8
EE-2	1610	86.9	75.6
EE-3	1605	84.8	73.8
EE-5	1600	77.5	62.3
EE-7	1605	73.7	70.0
EE-6	1605	73.5	63.4
EE-8	1605	73.4	68.3
BB-5, 6	1598	72.8	70.3
EE-9	1600	71.3	80.5
EE-10	1615	64.5	73.4
Average	1605	....	70.6

Active FeO in the Slag—The solubility curve gives the saturation value for FeO in iron under a slag of pure iron oxide. The distribution ratio curve is a quantitative statement of the relation between iron oxide in the slag and FeO in the metal and applies only to equilibrium conditions. The term "mol per cent FeO in the slag" refers only to that portion of the FeO which is free to dissolve in the metal and, as pointed out in the preceding paragraph, in lime-iron oxide slags all of the iron oxide is in such a condition. If stable compounds of FeO and another oxide are present the amount of FeO dissolved in the metal would be less than that predicted from the mol per cent of "total FeO" in the slag, but would be proportioned, by the value of the distribution ratio, to the "free" FeO content of the slag.

Solubility of FeO in Iron under Operating Slags—From the foregoing discussion it can be seen that the exact amount of FeO in the metal in equilibrium with a finishing open-hearth or Bessemer slag can not be predicted until data are obtained on the compounds present in such slags. The initial steps toward a knowledge of solubility of FeO in iron under commercial slags are determinations of solubility under slags consisting of FeO and SiO_2, and FeO, CaO and SiO_2. The distribution ratio curve, Fig. 1, may be used as a reference line for any determinations, as it gives the FeO in the metal which is in equilibrium with "free" FeO in the slag.

Furthermore, in open-hearth operation, equilibrium between slag and metal is seldom reached because carbon elimination is proceeding at all times, preventing the metal from taking up iron oxide to its equilibrium value. Under open-hearth conditions the amount of dissolved iron oxide depends on the carbon content of the metal and the temperature, unless of course, deoxidation with some other metalloid has taken place.

The rate at which carbon is eliminated is controlled primarily by the rate of diffusion of iron oxide from the slag into the metal and this to a large extent depends on the saturation value of FeO in the metal under the slag in question.

Inclusions in Pure Iron-oxygen Alloys—In polished sections, only one type of inclusion occurs, in the form of light-gray rounded areas of various sizes. These are probably globules of FeO, saturated with iron. In a sample with 0.90 per cent FeO the globules are all relatively small and comparatively uniform in size, as shown in Fig. 3a. With increasing FeO content above 0.94 per cent, a gradually increasing number of much larger inclusions is found, as shown in Fig. 3b, a melt containing 1.75 per cent FeO. Many of these are nearly perfect spheres, but most of them have rounded projections on the side, and appear to be in the process of growth by the coalesence of two or more globules. The solubility of iron oxide at the melting point is 0.94 per cent FeO. If the iron oxide content of the iron is less than 0.94 per cent, no iron oxide is precipitated on cooling the melt until solidification occurs. The iron oxide then appears as finely divided globules throughout the mass of iron. On the other hand, if the iron oxide content of the melt is above 0.94 per cent, iron oxide is precipitated in the liquid iron until freezing occurs and the globules so precipitated coalesce very rapidly. Fig. 3c shows a sample of 2.46 per cent FeO containing two large particles in the act of coalescing. This section was taken from the top of a slowly cooled ingot.

Acknowledgement

The writers wish gratefully to acknowledge the assistance rendered by W. A. Simkins, assistant analytical chemist, U. S. Bureau of Mines, who developed the apparatus and performed the analyses for oxygen. They also wish to express their appreciation to R. L. Geruso and S. P. Watkins, research fellows, Carnegie Institute of Technology, for their part in the experimental work.

Blast Furnace Operators Meet

At a one-day session of the Eastern States Blast Furnace and Coke Oven Association held in Pittsburgh on February 17, several phases of practice, having a pronounced bearing on furnace operation, elicited lengthy and earnest discussion. Although on the program many topics were listed for consideration there were, as usual, a few of these topics which aroused especial interest. Such topics were developments in gas cleaning, use of high temperature blast, size of large bell in relation to stock line diameter and its bearing on flue dust losses, dry cleaning of coal, and the relation of melting point of coal to the quality of coke produced from it.

During the morning there were two sessions of the association; one for those interested in subjects relating to the blast furnace and the other for members concerned with the production and use of coke. The former session was presided over by H. A. Berg, vice president of the A. G. McKee Company, and the latter by H. P. Zeller, vice president of the Donner Hanna Coke Corporation. The session in the afternoon was a joint one for all members; it was in charge of Chairman E. T. McCleary, vice president of the Youngstown Sheet & Tube Company.

After the dinner the evening meeting was opened by the president of the association, C. R. Meissner, superintendent of the coke plant of the Weirton Steel Company. Mr. Meissner spoke briefly and then introduced Mr. F. H. Wilcox, vice president of the Freyn Engineering Company, who chose as the subject of his address, "Blast Furnace Practice in Europe."

The discussion on the cleaning of gas brought out a unanimity of opinion on the desirability of dry cleaning by means of which process a large percentage of the dust in the gas delivered can be removed. Tests made at furnaces of Youngstown Sheet & Tube Company, according to Mr. H. S. Braman of that company, disclosed that by passing the gas through a dust catcher, a whirler and finally through wet washers, approximately 99 per cent of the dust is taken out. Blast furnace gas laden with dust was contrasted with the waste gases carrying powdered coal ash.

As regards the use of high blast temperatures, opinions were quite divergent. Temperatures varying from 1250 deg. to 1600 deg. F. were stated to give satisfactory results provided the burden was of the proper make-up for a particular temperature.

The installation of a small bell causes an enlargement of the stock line and a consequent decrease of the gas velocity in the furnace top with the result that the loss of flue dust is decreased, stated one speaker. A large bell, while it assures a better stock distribution, results in a greater discharge of flue dust from the furnace.

An indication of the interest in the activities of the association is afforded by the fact that 180 members and guests were in attendance.

Causes for Bloom Croppage Losses

Steel Defects Discussed as to Their Sources—Difficulties in the Determination of the Responsibility and Remedies for Seams and Cracks

By G. D. JOHNSON

THE practical metallurgy of steel is so complex that it is exceedingly difficult to trace the quality or defects of the finished product to some definite stage in the process of manufacture. The "yield," the watchword of manufacturers, serves as a good illustration of this point, and it is not without interest to follow the successive steps in the production of a heat of steel and to concentrate on those stages directly responsible for the production.

Not wishing to cover too much ground it seems best to eliminate all losses due to self evident causes, like badly rusted scrap, heavy sculls in the ladles, overfilled molds, etc., and to deal with those operations which to all appearance bear directly on the percentage of the metal converted into satisfactory product. One of the best indices of this group of factors is blooming mill croppage.

As the amount of croppage is a function of quality, it has to be dealt with accordingly to the standards of the plant in which the steel is made. These standards vary in different plants, not only because steel that passes the requirements for rimmed type will not be acceptable, for example a plant making alloy steel, and alloy steel specifications will be ridiculous in a hoop mill, but largely because the term "quality" is exceedingly elastic and not all steel makers have the same ideals. It is better, therefore, not to go into minute details and reasons why a certain amount of croppage is accepted in a given mill, but to dwell rather on causes shifting this accepted average towards a larger figure.

The number of variables entering between the unloading of the scrap in the mill yard and the hot billets at blooming mill shears is so large that elimination of large groups of them may be made to a great advantage without interfering to any extent with the accuracy of the conclusions. A short observation will show, for example, that the amount of croppage in any ingot of a heat is not a constant for the whole train, bringing out the point that composition alone (the average analysis discounting usual segregations) is not the primary factor regulating the amount of unsound metal producing in the rolling. This in its turn leads to the conclusion that something taking place between the time when molten metal of uniform composition left the ladle and solid metal entered the rolls of the bloomer had effected a pronounced influence on the steel but not to the same extent in each ingot into which a ladle was divided.

To reach this conclusion, simple as it appears, presupposes a very considerable amount of careful study directed towards verification of the influence of the components entering the blooming down operation, namely: quality of soaking, temperature range selected and used and similarity of mechanical features of rolling the consecutive ingots of a heat. Only an absolute certainty that all of them are identical for a given heat permits of an opinion that the cause of different amounts of necessary croppage originates before the ingots are charged into soaking pits. This is one of the few points which will not raise an argument among men well versed in rolling. Many will agree that one heat may roll better than the next, but that no amount of care and vigilance in soaking and rolling will procure ingots everyone of which will be delivered on the cooling beds as a billet of exactly the same quality as its neighbor.

In studying the interval between the molten metal in the ladle and the ingots as charged in the soaking pits it is necessary, in order to avoid the introduction of too many details, to accept teeming practice, the very substance of the interval just mentioned, as an integral of the many factors constituting it, largely controlled by the type of steel, temperature at which the metal leaves the nozzle and the design of the molds.

By type we refer to the degree of deoxidation to which the bath was subjected principally in the furnace and the ladle but sometimes in molds. General practice distinguishes three sharply divided classes, fully killed quality metal, wide open rimmed steel of tonnage plants and a combination of the two, partially killed steel of some small independent plants. A marked difference in distribution of gaseous constituents is typically characteristic of each of these types and perceptibly affects the behavior of ingots in the rolls.

Fully killed steel does not contain when leaving the ladle any gas not tied in some component so that on cooling none of it escapes in free state. Overoxidized rimmed steels have most of their gas in solution instead of combination and lowering temperature leads to decreased solubility resulting in rapid evolution of gas. Partially killed metal stands on the border between the two types described.

Any metal passing from molten to solid state shrinks. In a mold filled with steel the metal solidifies towards the inside which chills the last. The contraction of volume has to be compensated. In case of killed steel a supply of hot metal filling the central zone of the ingot has to be furnished. If it is not provided by means of a hot top or a similar device a cross section of such an ingot will show a perfectly sound metal from outside to the center, but the center itself will be represented by a conical cavity in exaggerated cases reaching to a few inches from the bottom. The same laws govern solidification of open steels but lowering temperature in that case sets free dissolved gases. Rapid solidification at the surface prevents gas bubbles from escaping and they are caught in the metal forming so well known blow holes. Heat insulation created by continuously growing layer of solidified metal decreases the speed of heat removal and the gas set free in inner layers of an ingot has time to rise to the surface. It could escape then in the atmosphere, but as a rule the

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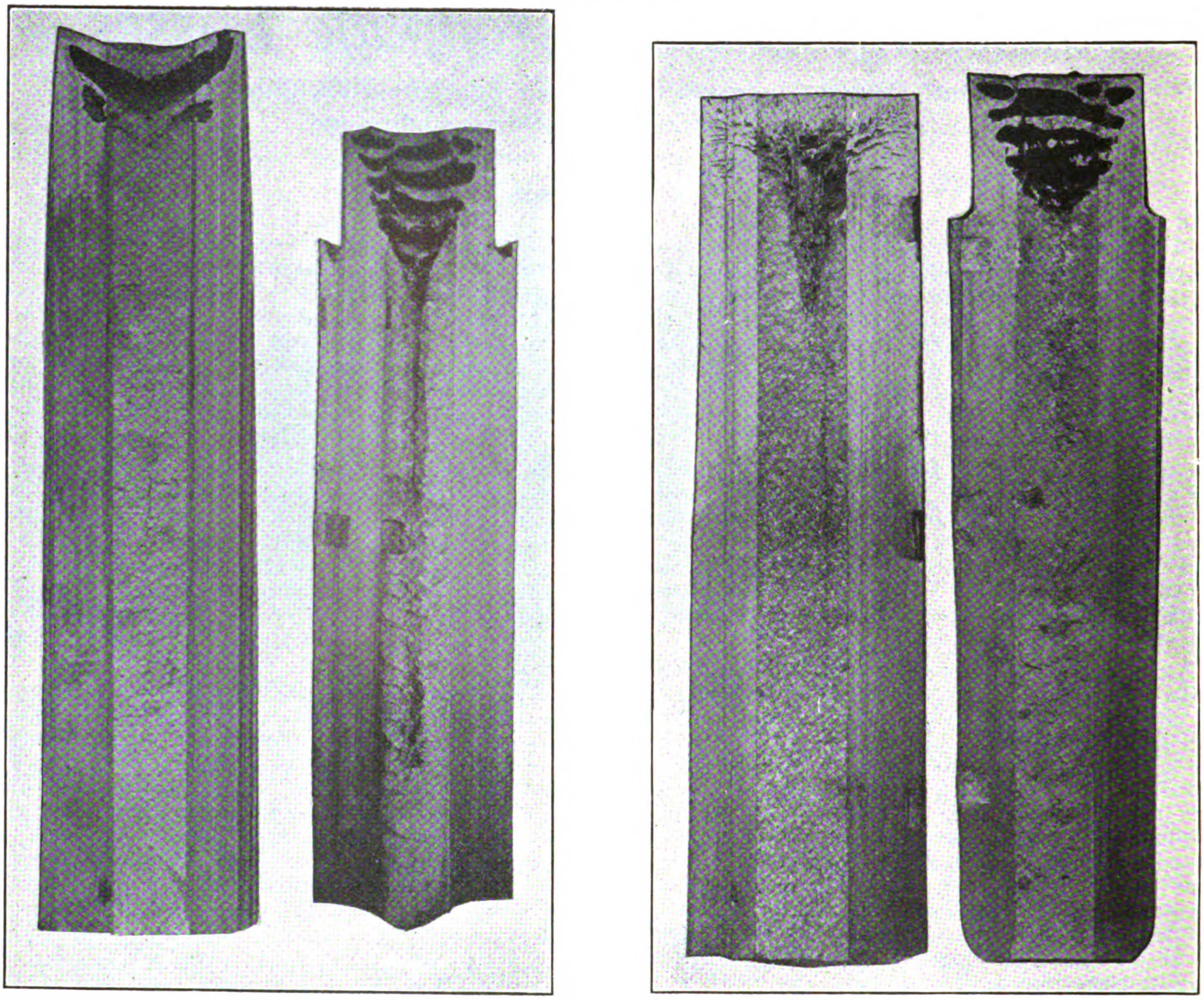

FIG. 1—Showing various shrinkage cavities and pipes in ingots.

radiation of heat from the top of ingots is fast enough to form a crust long before the metal of the center has solidified. Gas bubbles reaching it are stopped in their progress until their accumulated pressure pierces a hole in the crust or raises it resulting in "growth" of ingots. The cross section of a rimmed steel ingot shows a multiplicity of small holes near the outside surface, freedom from them near the center and one large but short cavity near the top caused rather by rising of the outside layer than a decrease in volume as is observed on deoxidized steels. In semi-killed steels a compromise is effected. Insufficient amount of deoxidizer increases the number of outside holes reducing the total contraction of the volume to such an extent as to counteract the necessity for formation of central cavity inevitable in fully killed metal but is not sufficient to cause the growing of ingots. The latter is usually further prevented by warming up the top of the ingot by addition of some aluminum to the almost completely filled mold.

Steel after blooming is scrapped for two reasons, the steel may contain internal defects or its surface may present undesirable features which either cannot be eliminated at all or the cost of this operation would be too great. Close attention to the former is imperative for the production of the best physical characteristics and the inspectors are instructed to watch closely for the presence of any discontinuities of the metal, non-metallic inclusions, imperfectly welded blow holes and segregation.

Non-metallic inclusions usually occur either completely segregated or in comparatively small masses. In the first instance they form the central pipe of a killed ingot, in the second they are distributed reasonably uniformly throughout the whole mass of the metal as it is observed in rimmed steels. Blow holes often go hand in hand with non-metallic inclusions because, though oxygen does not always reach their internal surface and good welds are entirely possible, solidification phenomena accompanied by selective crystallization drive more fusible slag particles from the growing dendrites into voids formed by the presence of gas where they are entrapped. The influence of oxidation is markedly pronounced only in the case of the large top cavity and the open shrinkage pipe of killed ingots connected with it where freedom from oxidation is exceedingly rare. Cropping of successive sections from the killed steel bloom has to be continued until the last traces of pipe are gone, while in open steels the quality of the metal cannot be improved by cropping. It is not difficult to see that in the first case the amount of croppage will be specified by the character of the pipe which in its turn is governed exclusively by teeming conditions.

Surface defects fall into different groups. They are caused by improper rolling, by improper teeming and by pratice independent, at least at the first glance, of both these features. The first class hardly requires comment because it is self evident that overlaps, seams, marks, etc., found on a billet, after it was caught and badly mangled between the rolls and then straightened in some way, can be eliminated by greater caution in rolling. Seams due to splashed molds, scabs, etc., will be cured when teeming is conducted so as to prevent them. In certain instances the relation, though not distinctly clear, still can be traced to definite peculiarities in these operations as is the case with some seams. On the other hand there is a phenomenon showing a great influence on the final yield which, depending presumably both on teeming and rolling, cannot be controlled in either operation alone. This is cracking of ingots.

Locating the cause of cracking is a very interesting problem but it cannot be solved unless a great amount of thorough practical and theoretical study is done in the plant by competent metallurgists. At the present cracking is entirely matter of luck and nobody knows whose. Tonnage plants do not pay so much attention to it because if an ingot is not completely torn to pieces the seams produced by cracks do not interfere with the specific actions of certain stock, and defective billets are rolled and applied to such items so that the excess cost is not so great. Alloy steel makers however would be exceedingly glad to eliminate them even at a considerable expense in order to save cost and delays incurred by extensive chipping, but at this time and quite probably for some years to come the question will remain unanswered because too many variables have to be studied and the means for their regulation will have to be discovered.

The fact that blooming mill practice enters the set of conditions causing cracking can hardly be disputed, but to what extent still remains to be determined. With very rapid rolling and especially with rifled rolls the stresses produced in ingots are often sufficient to overcome the cohesion between groups of crystals of normal size existing in ingots made with greatest care. There is a possibility that the presence of excessively large crystals principally represented by long acicular grains of the skin of many steels especially with rather elevated alloy content shows its influence by reducing the resistance to rolling deformations even under normal rolling speed and reductions. Cohesion between constituents of steel is least pronounced at the grain boundaries of the crystals and, exaggerated by the excessive size of the latter, is liable to show itself in numerous fissures perpendicular to the direction of maximum deformation in rolling. Against this assumption arises the everyday observation that cracks very seldom occur in groups, or evenly distributed all over the length of an ingot. In usual practice one or a very few cracks can be seen on a bloom suggesting that besides the general weakening of the metal by excessive crystalline growth there are probably some local disturbances expressing themselves in cracking. Grain size of the skin is largely influenced by teeming practice. Many experiments have been made in order to reduce their dimensions but, to writer's knowledge, a diminution of the grain size of the skin did not always lead to reduced cracking.

The lack of a direct relation between the character of the outside layers of ingots and their rollability is demonstrated by the behavior of killed and open steels. If introduction of definite areas of weakness in the skin of an ingot would be directly connected with the reduction of its quality as a metal for rolling, it would seem that every open ingot should roll worse than steel of the same analysis but properly deoxidized to insure a complete freedom from dissolved gases. The skin of an open ingot, abundant in blow holes distributed far from uniformly presents a very favorable ground for comparison of the effect of the planes of weakness on the behavior of steel between the rolls. It is opposed to more or less uniform, or at least symmetrical, location of strains in killed ingots. Still, checking his own experience, a rolling mill man may recall instances of stainless steel ingots leaving the rolls in the shape of a herringbone while open steels did not show a crack.

This brings out the question of temperature, both teeming and rolling. The importance of the latter is the basis of correct rolling practice and there would not be any common ground in the discussion of rolling problems without the tacit assumption of the correctly selected rolling range. Teeming temperature has a marked influence but it is hard to draw any conclusions regarding the extent to which cracking is affected by it. In open steels proper regulation of the teeming range will control the size and location of blow holes bringing them to the surface or forming so called deep seated blow holes, but there is no definite proof that they show their presence by increased amount of cracks besides influencing somewhat the number of seams. Crystalline growth of metals so strongly dependent on teeming temperature again eludes association with cracking because some alloys with inherently enormous grain size roll as well as any other steels.

There is a general tendency to think that open steels are more susceptible to cracking, and this point of view is seemingly, supported by facts. One has, however, to take into consideration the metallurgical properties of an iron alloy saturated with oxygen besides accounting for the influence of an unsound skin. There are no reasons for thinking that the oxygen bearing compound does not act as does sulphur in low manganese metal, i.e., rendering steel red short. In the writer's experience it was often observed that overoxidized skelp did not crack as much as overblown Bessemer stock, even though the split ingots presented an identical appearance and the mechanical treatment as well as the analysis were practically the same. The word "practically" will most probably induce scepticism, but in this case the analysis of components other than gases was actually checked with proper care in every instance; and there were no exceptions to the rule of the general behavior of these classes though the number of recorded heats ran into hundreds. One is tempted to advance a theory that the degree of oxidation possible by direct contact of hot gases with metal as takes place in a Bessemer converter is not the same as when the reaction occurs through a medium of slag cover and ore addition characteristic of open hearth practice.

Commenting on teeming practice it is not difficult to see that the conditions determining the character of the teeming of each individual ingot change gradually and uniformly. The temperature of the ladle drops slowly and uniformly from the first to the last mold. The speed of filling is inside of a range limited by a few seconds, discarding rare occasions of frozen stopper and similar troubles. The temperature of the mold walls, an item of a very great importance, may be considered as a constant for a given train because in the majority of cases the train is not broken up in stripping and therefore all molds receive the same treatment when, for example, they are immersed in mold wash or left to cool in the air. Little variations in the surrounding conditions hardly bear heavily on the final results because they are to a very great extent neutralized by the mass of the molds.

Now, if it is assumed that the character of skin depends entirely on teeming conditions and rolling properties are governed by it, one has to expect a periodical behavior of a train of molds between the rolls. If a chosen set of conditions as just referred to demonstrates itself by freedom from cracking, it is natural to think that in a train during the teeming of which these conditions were fulfilled at least on some molds they will demonstrate themselves by especially satisfactory results and the rolling quality of ingots will change proportionally to their distance from the molds poured under ideal conditions. Everyday practice points out that no relations of this sort are observed. If any definite relation is present there would not be any difficulty in checking a couple of hundred heats of the same analysis to see if the amount of cracking can be expressed as a function of teeming conditions. There are no records showing the correctness of this assumption though many similar experiments have been conducted.

Soaking pit practice, the only intermediate step between teeming and rolling, may be considered a serious handicap for correct interpretation of observations directly connecting teeming with the amount of cracking were not the basic principle of this operation, even distribution of heat, fully accomplished. With the present design and construction of pits there are no chances for sharp local overheating or chilling of the areas on which cracks may subsequently develop due to rolling outside of the proper range.

Concurrence of opinions points out that smaller size and closer approach to circular cross section tends to diminish, other conditions being equal, the destruction of the continuity of the billets by the pressure of the rolls. This creates a new avenue of approach when the influence of the skin can be disregarded and the phenomena occurring during the first moments of solidification are studied unimpeded. A thin layer of solid metal formed during the first few seconds of solidification shrinks from the walls of the molds and is therefore obligated to withstand the pressure of liquid metal for which it forms an envelope. In some instances ferostatic pressure is sufficient to break it and to allow a small amount of liquid to run through forming simultaneously a seam and a plane of weakness inductive to future cracking. This temptingly simple explanation does not withstand investigation because while according to the laws of hydraulics these cracks would and do form parallel to the long axis of the ingot, cracking between the rolls in the majority of cases takes place in the direction perpendicular to it. The possibility of formation of planes of weakness due to hanging cracks is so far remote with the present careful handling of molds that such a hypothesis has to be abandoned at the very beginning.

The tendency for cracking of ingots with unequal sides may point to some factors which might contribute to the correct understanding of the basic factors underlying this phenomenon. If one has to dismiss the possibility of cracking as being caused by planes of weakness created by ferrostatic pressure, one cannot disregard the influence of the unbalanced distribution of cooling stresses. They are governed, probably, by the equations of heat transfer depending on the type of receptacle in which solidification takes place. Uneven cooling from the outside to the center presumably surrounds groups of crystals, sometimes of quite a large size, the layers of grains stretched by cooling forces to a very considerable extent, with corresponding reduction of their resistance to mechanical deformation. In rolling compressive stresses do not destroy the continuity of an ingot, but the lengthwise pull of the rolls often is able to overcome the resistance of these stretched areas with the resulting cracking. This point of view, though by no means proven, is supported partially by the greater abundance of cracks on flat ingots, the very greatly reduced amount of cracks on polygonal and especially on fluted ingots and the pronounced independence of this phenomenon from other characteristics of mold design than cross section.

The percentage of yield, though determined at the blooming mill shears, depends but very little on blooming down. It can be said that, if the ingots were perfect, losses may be expected only in exceptional cases. The greatest influence on killed steel croppage is caused by pipe and on open stock by the opening and oxidation of top cavity. The first is usually corrected by the use of properly designed molds supplied with hot tops. Top cavity in open steels can be, if not removed, at least greatly reduced either by bringing it as close to the top as possible by keeping the upper layers of the metal hot, or placing it so well inside of the ingot that roll cannot open and oxidize it which is achieved by chilling the top as soon as practicable after teeming. Surface defects caused by cracking of both types have eluded explanation and control.

Cold Rolled Axles

Axles are successfully made by the cold rolling process in sizes up to about 5½ in. diameter. The bars are hot rolled from blooms, after a 25 per cent top, and 5 per cent bottom discard, to size within 1/16 in. and 3/16 in. of the finished requirement depending on the size range. The chemical range as applied by ladle test is as follows:

Carbon .26/32, mang. .60/80, phos. limit .03, sul. limit .05.

Material so prepared is suitable for use in axles for street cars, mill buggies, mill and mine cars, tractors, etc., and in stamp stems. The cold drawing process is unsuitable for the production of the grade employed above because cold drawn material in the required sizes and analysis will not endure repeated stresses. The physical tests of this material show very high elastic limit and good ductility with good endurance, and it is excellent in service.

Starting Alternating Current Motors*

Methods of Starting Squirrel Cage Induction and Synchronous Motors Are Reviewed as Affecting Driven Machinery, Power Supply and the Starting and Motor Equipment

By C. W. FALLS†

LET us begin by analyzing the situation as it is today to determine whether there is a real need for a change from the long established standard method of starting squirrel cage induction motors and synchronous motors.

Suppose we consider first the machinery to be driven. How has it changed in the past several years? Fundamentally, in many industries, it is actually not much different. There has been a decided trend toward more direct connection. In some lines, motors have been mounted on or even built into the driven machine. Many belts have disappeared although there is still a goodly number. Long center drives have given way in many places to special short center arrangements to economize in floor space. Machinery in many industries is being concentrated in small areas as never before to conserve space and eliminate unnecessary handling of product undergoing manufacture.

From the driven machinery viewpoint, then, there is evidently little change to influence the selection of control, unless it is the matter of conserving space.

Suppose we consider the situation from the power supply angle. Central stations have grown enormously in size in the last few years. Distribution systems have likewise grown, permitting the purchase of power in large blocks. Interconnection of systems is becoming common, giving a continuity of service never before obtained, although there seems to be an increase in the number of momentary dips in voltage. For densely populated areas, network systems, furnishing both power and light, are being established and, for the time being, seem to make necessary more stringent starting current limits for those areas, because here voltage dips must not exceed two volts on account of the possibility of obtaining flickering of the lights.

What about changes in motor design? There have been developed lately moderate and high speed synchronous motors suitable for general purpose application, whose starting torques and currents are practically the same as induction motors of equal ratings. Inasmuch as the starting problem from the torque and current standpoint is the same for these synchronous motors as for induction motors, all of our considerations concerning squirrel cage motors will apply equally to the synchronous machines.

Squirrel cage induction motors of four different varieties have been developed. To the ordinary design have been added three motors designed particularly for full voltage starting; namely, (1) the high resistance rotor machine, having high starting torque and high slip, particularly applicable to flywheel loads. (2) the normal torque high reactance motor, having low starting current, but otherwise about like the ordinary squirrel cage motor, and (3) the high torque high reactance of double squirrel cage motor, also with relatively low starting current. We will consider the characteristics of these different machines later.

Method Most Widely Used

Now, do these changes in the power system and in the types of motors at our command make necessary a change in our methods of starting motors?

The standard method in general use for many years has been the auto-transformer or compensator method, giving reduced voltage, for motors larger than 7½ hp., while full voltage starting has been standard for motors 7½ hp. and smaller. A failure of this practice to fully meet the needs of all concerned would undoubtedly have led to a general change long ago.

If it had been handicapping electrical development in any way, would electrification in this country have outstripped the countries of Europe to the extent it has?

Has not the fact that, through the use of an autotransformer, the starting current of a squirrel cage motor can be very appreciably lowered, fostered the use of the simplest and least expensive type of motor in this country—that is, the squirrel cage motor—and thereby contributed largely to the rapid electrification of industry and the tremendous growth of power systems, by building up the power load?

If such is the case, then our enthusiasm to change should not be allowed to sway us to the use of other methods unless these methods proposed have decided and far-reaching advantages. Will they carry forward electrification rapidly or retard it through failure to measure up to all the requirements of real general purpose starting equipment?

Now just what is a compensator or autotransformer starter and what does it do?

1—It is a self-contained voltage reducing device by which the line current of a motor is reduced (as the square of the voltage) to a lower point than is possible to obtain by any other way, for the same torque.

2—It is practically independent of the design of the motor to which it is applied, and, therefore, either a high or low speed motor of any manufacture can be started by the same autotransformer starter.

3—The underwriters and manufacturers have agreed that a general purpose starter, to avoid becoming a fire hazard, should have capacity enough to stand a test of 300 per cent current for 15 seconds out of every 4 minutes for 1 hour without exceeding a temperature set by the A.E.S.C. as a maximum permissible value. Inasmuch as compensators for years have been designed to meet this test, they have gained an enviable reputation of being heavy duty starters. They have handled general applications with remarkably few cases of trouble, though frequent and heavy starting duty has often been encountered.

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†Industrial engineering department, General Electric Co.

4—An autotransformer starter affords complete protection to the motor, is self-contained, and, for a current-reducing device, takes the least possible space for the duty to be performed.

It is obviously possible to draw a high current from the line even when a compensator is used if it is improperly handled, but this is also true of any hand device and can be prevented only by properly instructing the operator or going to a magnetic device.

When properly operated, a very low value of current can be obtained for a given starting torque. True enough, there is the magnetizing current of the autotransformer to be added to that drawn from the line and it is a lagging current. However, designers of autotransformers keep this at a very low value so that in a properly designed compensator it adds not more than 3 to 10 per cent to the line current, depending on the motor design and the tap used. This obviously is a practically negligible value, compared to the total current at starting.

One point in connection with compensator operation which has been very much over-emphasized is the possibility of a transient current of a high value being obtained on throwing from starting to running, when, in the ordinary compensator, the motor is momentarily disconnected from the line. It is possible to find such a transient if you happen to hit a certain point of the voltage wave upon reconnecting and have an oscillograph to catch it. From a practical point of view, such a current, lasting for only a very few cycles at most, can have no observable effect on the system or motor until large motors are involved, say 200 or 300 hp. In such larger sizes, the effect may warrant special connections in the starter to avoid disconnecting from the line.

Obviously, if this feature did not affect the small capacity power systems of years gone by, it is ridiculous to think of it as possibly harmful with the much larger systems of the present day.

As a device for obtaining the least disturbance, for frequent starting, long starting periods, and general applicability, where squirrel cage motors are suitably applied, the compensator cannot be equalled as a one-step starter.

Other Methods Proposed

Why then are other methods of starting being adopted for certain drives and proposed by some for general use?

No doubt there are many contributing causes, but may I offer for your consideration the supposition that such factors as the desire for greater simplicity, the advent of magnetic control, and the development of high reactance motors have been of no little importance in bringing these other starting methods to the foreground.

The magnetic control business has experienced a most phenomenal growth and is still expanding. Improvements in the design of contactors, relays, canes and other parts have made magnetic devices for all kinds of motors exceedingly attractive, reliable, and compact. They prove extremely desirable since they permit remote control, automatic control, multi-station control, portable master control, emergency stopping, etc. Push-button-operated switches, with full protective features for throwing motors on the line, have likewise sprung into prominence. This year witnessed a remarkable development of smaller switches, of this sort, to meet the demand for switches which can be mounted directly on the driven machine. A 5-hp. motor starter is now almost small enough to fit into your pocket.

Now, with such small yet dependable magnetic devices available, it has been a natural thing for operating engineers to use them for starting ordinary squirrel cage motors on full voltage, as this combination is the simplest possible, it occupies the smallest space, and prevents abuse by unskilled operators.

Full Voltage Starting

Starting on full voltage is not new. The practice started a good many years ago and for some time, as you know, has been standard practice for motors up to 7½ hp., as most power companies do not object to the starting current of a 7½-hp. motor on full voltage. It has been standard practice in textile mills to start 25 hp. motors in this way. In central stations 200 and 300-hp. motors driving essential auxiliaries are frequently tied to the station bus. One prominent automobile manufacturer has for years been starting standard motors up to 75 hp. on full voltage. Cement plants have used this method for many drives, frequently involving motors as large as 100 hp. Limitations of this method are not found in the motor design as motors can easily be made to stand this service. In fact, most general purpose motors up to 50 hp.—1800, and larger sizes at slower speeds, are quite suitable without change. But, rather, the limit is in the kva., which can be taken from the line and the strength of the connecting link between the motor and its load.

While power-company-starting-current rules have in general not been materially changed in the last 12 to 15 years, and, therefore, users with one or two motors have been forced to retain current-reducing starters, the number of consumers with large connected loads has multiplied rapidly. In the plants of such consumers full voltage starting can be and is practiced with large motors. To this increasing number may be added a large number of plants producing their own power on a large scale. So the practice of full voltage starting of squirrel cage motors is well established and increasing.

Where this method has been used, maintenance costs are low and no difficulty is experienced if proper application practices are followed. For belted loads ample sized pulleys and belts, of course, are essential. Direct connected drives offer no particular problems except with machines or devices which might be injured by the sudden application of a high starting torque. Chain or gear driven machines may have enough slack in the various parts as to make a different method of starting desirable.

Mention has been made of the effect of the maximum torque on the driven machine during acceleration. In the general application field this does not appear to be a serious factor. The driven machinery is practically always designed to stand some overload and the motor is selected with this in view. If designed for overloads that the motor can stand, it appears that the driven machine has ample strength to withstand the maximum torque of the motor applied gradually during acceleration.

Paralleling the advent of magnetic control devices was the development of the newer squirrel cage motors, designed for full voltage starting, which have previously been mentioned as "high-reactance" ma-

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chines. One of the chief aims in the design of these motors was to reduce the starting current to roughly 70 per cent of that of the ordinary squirrel cage motor.

The curves I have here will give an indication of how these various induction motors compare in current and torque characteristics. The first set of curves (Fig. 1) shows the current plotted against speed. The highest current is, of course, taken by the ordinary squirrel cage motor, as indicated by the curve marked KT. The high resistance rotor machine is usually designed with a lower starting current, as indicated by the curve marked KTR. The curves marked FT and FTR are for the more recent high reactance designs, the FT curve being for the normal starting torque machine, while the curve marked FTR is for the high starting torque motor. The current taken at starting by these two motors is approximately that which would be obtained with the ordinary squirrel cage motor and a compensator connected to the 80 per cent tap. It is possible to design such motors for even lower starting current at a sacrifice of other characteristics, but, inasmuch as the values shown are usually satisfactory for most power systems, motor manufacturers do not make a further reduction in starting current of the standard high reactance motors, preferring to keep the other characteristics as high as possible.

The torque speed curves of these motors (Fig. 2) give an indication of the field of application for each of the various designs. The curve of the ordinary squirrel cage motor needs no particular comment. The high resistance rotor machine exerts approximately its maximum torque at starting and is, therefore, suitable for loads requiring high starting torque. However, it will be noted that its slip at full load is some three times greater than that of the other squirrel cage motors. This limits its field of application to applications involving frequent starting and very short running periods or to loads having flywheels and rapidly recurring peak loads. For these applications the high resistance high slip motor is ideal as it permits the flywheel to deliver some of its stored energy to help carry the machine through the peak loads. The high torque high reactance motor is particularly applicable to those loads requiring high initial torque, but ordinary squirrel cage characteristics at full speed. Examples of such applications are conveyors which run for long periods and small compressors started without unloading.

The high reactance motor, indicated as the normal torque design, obviously can be applied wherever the ordinary squirrel cage motor has been applied, inasmuch as their initial starting torques are about the same and its maximum torque is at least 200 per cent, which is generally considered sufficiently high for practically all general purpose applications. It might be mentioned that the initial starting torque of this design can be varied considerably in designing a motor to closely fit the torque requirements of a particular driven machine. However, a design, giving the torque curve shown here, seems to be quite widely acceptable for general purpose work.

The development of these high reactance motors has increased the field for full voltage starting in three ways. First, the small power consumers have seized upon the combination of high reactance motor and magnetic switch as a means of meeting the power-company-starting-current rules and yet obtaining full automatic operation with low cost and utmost simplicity. In the second place, high reactance motors can be designed with torque curves to exactly fit the driven machine, eliminating the question of excess starting or maximum torque, and, therefore, also eliminating the necessity of a current and torque reducing starter. Third, the "high torque high reactance" motors are being applied to loads where, heretofore, only wound rotor or slip ring motors have been used.

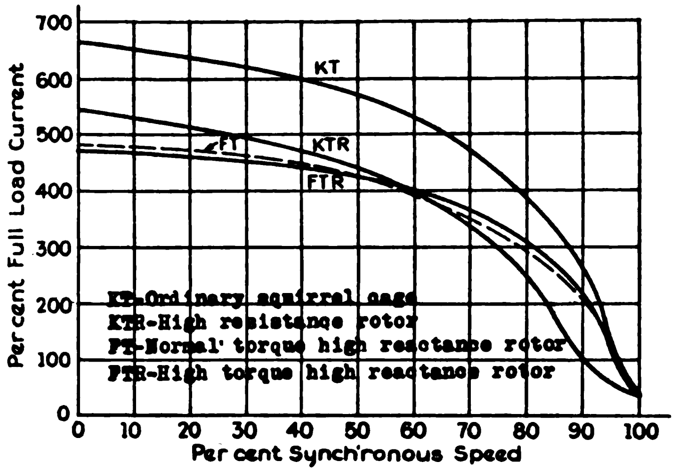

Fig. 1

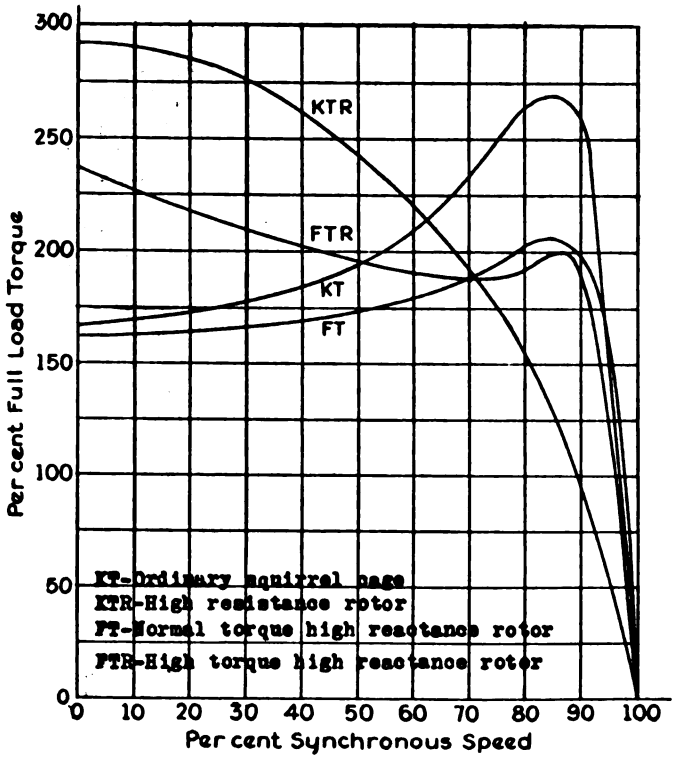

Fig. 2

Full voltage starting obviously involves taking more power from the line, but for a shorter time and, therefore, the actual energy consumed is less than with other methods. Where there are several motors in an installation, the practice of full voltage starting will rarely bring the kw. demand of the starting period above that of the running period as, in a large installation, the motors are not all started at the same time.

Now since there are available these various kinds of squirrel cage motors designed to more nearly meet the torque requirements of the driven machines and yet satisfy the demands of power companies as to starting current in sizes up to about 30 hp., there appears to be no reason why full voltage starting will not become quite generally the practice, at least up to 30 hp.

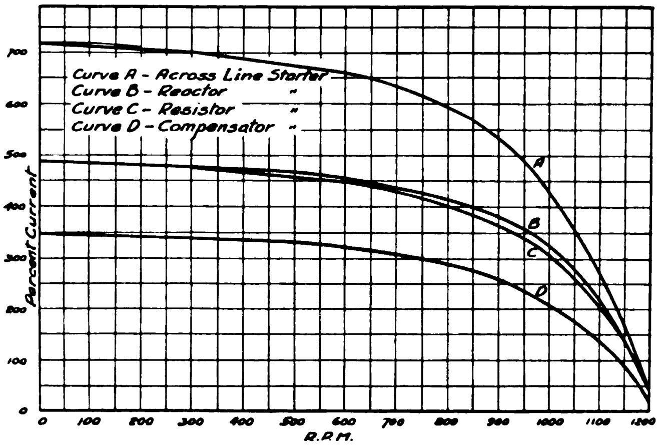

Fig. 3

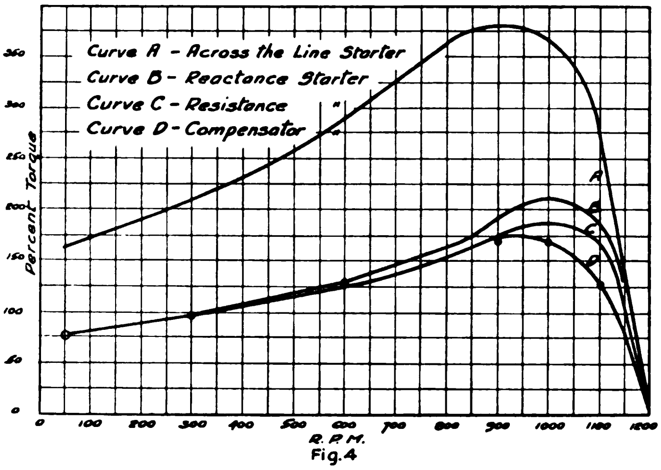

Fig. 4

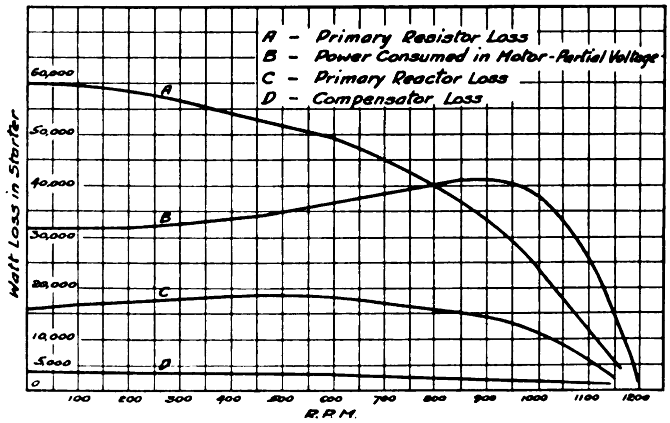

Fig. 5

The Resistance Method of Starting

The method of starting squirrel cage motors by inserting series resistance which is short-circuited as the motor reaches full speed is, of course, very old, being a method borrowed from direct-current-motor-starting-practice.

While it has been with us as long as the compensator, the use of the resistor starter has been confined largely to very small motors. This is not surprising when its relative effectiveness is considered. It reduces the line current in proportion to the reduction in voltage at the motor terminals—65 per cent voltage at the motor means 65 per cent of the locked rotor current of the motor drawn from the line. Started by a compensator giving 65 per cent voltage at the motor means 65 per cent of the locked rotor current of the motor drawn from the line. Started by a compensator giving 65 per cent voltage to the motor, the line current drops to about 42 per cent of locked rotor current. With a motor, say of 50 hp., 220 volts, this difference might easily amount to as much as 200 amperes, which is approximately twice the normal full load current of the motor.

While the reactive component of the starting current may be a few per cent higher with a compensator, the total current taken when using a resistor starter is so much higher (for the same torque) it cannot help but have a more harmful effect on the feeder voltage.

The resistor starter in addition to drawing more power from the line than a compensator is a consumer of energy on a fairly large scale and this energy must be dissipated by the starter. For example, let us take the case of an ordinary 25 hp., 440 volt squirrel cage motor for which full test data were obtained when it was started by four different methods. This set of curves (Fig. 3) shows the current plotted against speed when this particular motor was started, first, on full voltage (Curve A), then by a series reactance (Curve B), next by a resistor starter (Curve C) and lastly with a compensator (Curve D). These curves simply show that the same relation, as had been mentioned before, holds, namely, that the compensator reduces the line current as the square of the voltage, whereas the resistor and reactor methods reduce the current only in proportion to the reduction in voltage. The next set of curves (Fig. 4) shows the speed torque curves obtained by starting with the four different methods, the same voltage being applied at the motor terminals at starting for curves B, C, and D. It is evident that starting on full voltage will bring the motor up to speed in the shortest time, but that with the other three methods there would be very little difference in the time of acceleration, regardless of which of the three were used. The next set of curves (Fig. 5) shows the watt rate of consumption of the motor and of the three partial voltage starters during acceleration of the motor. It will be seen that the compensator consumes at the lowest rate, the reactor comes next, while the resistor starter consumes at the greatest rate of all. These curves represent the most important difference between these types of starters.

In the case of this motor, which is typical for most any size of ordinary squirrel cage motor, the watt rate of loss for the resistor was some 15 times that of the compensator. This means that the compensator must start the motor 15 times to consume the amount of energy taken by the resistor at one start, or the compensator must start the motor four times to equal the loss of the reactor for one start. The saving in energy by one method over the other is not of particular importance, unless very frequent starting is involved. But rather it is the effect of this difference in the design of a starter which, to be generally applicable, must be enclosed for safety reasons and compact and easy to install.

To meet the test, recognized by the underwriters, the manufacturers of starters, the institute, and the A.E.S.C., as a proper and not too stringent one for a general purpose starter (namely, three times full load current for 15 seconds out of each four minutes for one hour, without reaching a prescribed temperature), the resistor starter would need to have about 15 times the radiating area of the compensator, or else 15 times the temperature for the same area, or some compromise between these values.

A close study of such facts and other test data indicate that a resistor starter can be designed for small motors where the total watts to be dissipated in the starter can be dissipated within the enclosure without materially raising the contacts and other parts of the starter to an undesirable temperature. With larger low voltage motors the amount of energy to be handled becomes greater and difficulties with heating are multiplied.

There is the feature of simplicity to be considered. A resistor can be short-circuited and this simplifies somewhat the switching problem in the design of the starter. Furthermore, it is an easy matter to repair or to replace a resistance unit. Therefore, where space is not at a premium, where these features of simplicity are worth more than reduction in starting current, and where only a slightly reduced torque is desired, the resistor starter should find a ready application.

For the network systems which have been mentioned before, where the voltage dip must not exceed two volts because of the possible effect on lighting, the "multi-step" resistor-starter has a field of application as it can be designed to permit building up of the initial starting current in small increments which will not affect the system voltage beyond the two volt limit. In such a starter the heating problem is still present, but, inasmuch as the series resistor lends itself to multi-step starting better than other methods, because parts of the resistor can be shorted out at intervals without complicated switching, it is used for such starters. Obviously, however, a multi-step starter of this sort will be more complicated and of smaller capacity than is desirable for general industrial application.

The Reactor Method

The reactor method of starting is subject to the same remarks as applied to the resistor method. For a given torque the current reduction effected is small, and, since there is a large reactive component, with pure reactance in the circuit, the line disturbance may be considerable. Furthermore, judging from the data just mentioned for a 25 hp.-440 volt motor, the heating may easily be four times that of a compensator.

The fact that it is hardly possible to bring out taps and short circuit parts of a reactor at intervals during the starting period limits this method to one-step starting.

It might be mentioned in closing that the reactor starter may sometimes prove advantageous in starting large synchronous motors by reason of the fact that it permits the voltage at the motor to rise as higher speed is attained and this gives the motor additional torque just when it needs it to pull into synchronism. Switching is simplified and, with air core reactors, heating is not a serious problem.

To summarize the situation of methods of starting squirrel cage induction motors and synchronous motors as it appears today, the trend seems to be toward a more general use of full voltage starting of motors up to 30 hp. and probably on up to 50 hp., through a proper utilization of high reactance squirrel cage motors having low or normal starting torque and low starting current.

For general industrial use, the compensator still should be the most generally used device where low starting current, reliability, low first cost, for a capacity for repeated starts, and space are factors of importance. The resistor starter should find a limited field where the gradual application of torque and current are important. The reactance starter does not appear to have a very great field of application except in large motors where the starting duty is light. If the distribution system can stand the high current required by a reactance starter, it would seem that, for a general purpose motor application, more effective results as to first cost, reliability, and simplicity could be obtained by the use of full voltage starting of motors designed for the particular service.

Flat Rolled Steel Companies Form Institute

Arrangements are under way to merge under the name Flat Rolled Steel Institute, headquarters in Cleveland, Ohio, the three associations of manufacturers of sheet and strip steel. George H. Charls will be president, E. Theodore Sproul, one of the two vice presidents, and A. N. Flora, the other. A committee has been appointed to plan the details for the conduct of the new body.

The associations involved are three in number. 1—The National Association of Sheet and Tin Plate Manufacturers was organized in 1916 in Pittsburgh of which Walter C. Carroll resigned some weeks ago as president to go to the Oil Well Supply Company, and the affairs of the association have since been directed by Walter E. Watson, vice president. 2—The Hot Rolled Strip Steel Institute of which George H. Charls, formerly president of the United Alloys Corporation, Canton, Ohio, has been commissioner since May, 1927. 3—The Cold Rolled Strip Steel Institute of which E. Theodore Sproul, formerly sales manager for Trumbull Steel Company and afterwards general sales manager for the Oliver Iron and Steel Company, has been commissioner since its formation in May, 1927. Mr. Flora has been connected with the Trumbull Steel Company as vice president in charge of sales.

Westinghouse Veterans Banquet

The fifteenth annual banquet of the Westinghouse Electric & Mfg. Company's Veteran Employes' Association, held on February 4 in Syria Mosque, Pittsburgh, was the most largely-attended affair ever held by the organization.

The chief speaker was Secretary of Labor James J. Davis, who declared that at 50 or 60 years of age, a man or woman is just as capable a worker as at 30.

"Many a time, I remember, when I was a boy at work in the iron mill," Mr. Davis said, "I saw a faithful worker who had rounded out 50 years of his life. The custom was to present him with a gold watch, in token of his age. But his discharge also was presented. But science has added years to the span of human life. Today nobody feels old at any age. The finest brain and the strongest brawn never can outwit experience. The veteran employe always is worthy of his hire."

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The POWER PLANT

Furnace Design for High Capacity*

Furnace Operation Is Here Set Forth as It Is Found in Plants of Modern Design—Construction of Furnace Walls, Bottoms, etc., Have Important Bearing on Combustion and Overall Economy

By E. G. BAILEY†

THE boiler furnaces of twenty-five years ago were relatively small, and rates of combustion up to 50,000 to 80,000 Btu. per cu. ft. of furnace volume per hour were not uncommon. The boilers were set low and absorbed so much heat from the furnace walls that maintenance of brickwork was not much of a problem, except at the clinker zone when burning coal. The principal difficulty was to secure complete and smokeless combustion.

Improvement in efficiency was made by raising the boilers, and year after year furnace volumes were made larger with each new installation. Better combustion and less smoke resulted from the higher furnace temperatures and lower rates of combustion per cubic foot of furnace volume, but more trouble from furnace brickwork was soon evident. This was to be expected as the ratio of areas of furnace wall to the boiler tubes exposed to furnace radiation had increased greatly and the brickwork was heated beyond the fusing point of the ash of much of the coal burned.

In an effort to avoid furnace-wall trouble the furnaces were made still larger, the walls were moved further away from the active flame, and the flame was "softened" as much as possible, especially in pulverized-coal-fired boilers. The refractory walls were still a serious source of expense for outage and repairs, and there was the added difficulty of getting the ash out of the furnace due to slagging of the boiler tubes or choking of the ash gates. These conditions resulted from heating the coal ash above its fusing point, and applied equally to stoker and pulverized-coal plants.

The accumulation of slag on the boiler tubes choked the gas passages and directly limited the boiler capacity. The remedy has been found in more complete combustion of the particles of coke before reaching the tubes and in the proper spacing of the front rows of boiler tubes. The use of soot-blower elements properly located and protected, supplemented by hand lancing in some cases, permits the satisfactory operation of boilers in this respect.

The removal of ash was made easier by the addition of air through hollow walls and ventilated blocks, or the addition of some waterboxes and cooling tubes along the slag line and in the lower part of the furnace. These meager remedies were successful in some cases and failed completely in others, the difference being largely due to the influence of the fusing point of the ash in the coal being burned or some unnoticed difference in the relative location of the boiler tubes for absorbing radiant heat from the furnace. The better-designed furnaces were often forced to higher ratings until trouble was again experienced.

It seems that furnaces represent the one structure that engineers have built without using a proper "factor of safety." If a better furnace is built it is forced to higher rates of combustion until it shows its weak point, or if a given rate is established, the desire to economize in first cost often results in a structure that has a factor of safety of less than one.

The present tendency of furnace design is to rectify this situation by greater turbulence in combustion and the building of furnaces that will withstand high rates of combustion continuously with minimum outage and maintenance expense. So many engineers in both the manufacturing and operating groups are working diligently on this problem that the economic answer will soon be worked out. It is the purpose of this paper to report some progress in furnace designs for high capacities.

From this brief history of the experiences of the past it is observed that the principal factors that should control furnace designs are:

1—Complete combustion with a minimum of excess air,
2—Controllable rate of combustion over a reasonable range,
3—Long endurance of furnace walls,
4—Prevention of slag on boiler tubes,
5—Removal of ash.

The principal difficulty with the earlier furnaces was largely that of securing complete combustion with a minimum of excess air. The furnaces were small and cold due to the proximity of the boiler heating surface, coal was burned on hand-fired grates or on overfeed stokers carrying shallow fuel beds with air coming through in stratified zones. Oil was burned with steam-atomizer burners, resulting in badly stratified flame. The early gas burners were equally bad in this respect, and the first efforts to burn pulverized coal in such small furnaces resulted likewise in poor combustion, plenty of smoke, and damage to the furnace walls.

The importance of mixing within the combustion chamber was forcibly pointed out by Breckenridge[1]

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*Abstract of paper delivered at annual meeting of the American Society of Mechanical Engineers, New York, December 5-8, 1927.

†President, Fuller-Lehigh Company.

[1] L. P. Breckenridge, Study of Four Hundred Steaming Tests, Bul. 325, U. S. Geological Survey, 1907, pp. 171, 178.

20 years ago. The work of Kreisinger, Augustine, and Ovitz[2] further elaborated upon the need for mixing, as well as the need for temperature and time, for complete and rapid combustion. Checkerwork, wing walls, and steam jets were suggested as means for producing mixture. It was recognized that "mixture" and "temperature " were very destructive to the furnace walls, and therefore "time" was emphasized as the most suitable means for getting the desired results, and furnaces of large volume with low rates of combustion per cubic foot have been the outcome.

Professor Breckenridge was right when he said that "mixing is what counts," and now that furnace walls can be built to withstand not only high temperatures, but the scouring action of violent mixing or turbulence, the time factor can be reduced and very high rates of combustion can be obtained with satisfaction.

To restate the foregoing, high combustion rate requires temperature, turbulence, and time. The best results are obtained when each of these three factors is at a maximum. As in all such matters there is an item of cost involved in obtaining each, and the problem is to work out the economical balance for the best all-around results.

If, instead of following the cycle of events in making the furnaces larger and larger, still keeping the flame stratified and free from activity, the earlier progress had been made along the line of turbulent combustion and better-constructed furnace walls, we should have arrived at the present position very much sooner. While the furnaces being built today are larger than the earlier ones, the rates of combustion are being increased until the Btu. developed per cubic foot is practically the same as was common pracitce 25 years ago. There is one advantage, however, in size, even with the same rate of combustion, in that the actual time factor for a given particle in the furnace is greater than if the furnace were small. In other words, there is a certain relationship between the size of the particle of fuel burned and the time which it should remain in the zone of high temperature with a given turbulence to complete combustion with a minimum of excess air. As we now see it, turbulence is a very important factor in bringing this about effectively, which is borne out by the development of forced-draft stokers, mechanical oil burners, turbulent pulverized-coal burners, and in the case of gas, more intimate mixture of the fuel and air as they enter the furnace, together with the higher velocities necessary to produce turbulence and continued mixing as the fuel is being burned.

Turbulent combustion with a minimum of excess air produces high temperatures, and high temperatures facilitate rapid combustion, therefore completing it in a minimum of space. Considering combustion alone, we should use only uncooled refractory walls and have the furnaces as hot as possible. High furnace temperatures are equivalent to high-heat potentials and are analogous to high steam pressures and high-voltage electric currents.

The extended use of air preheaters has a twofold advantage: first, in recovering waste heat from the flue gases, and second, in accelerating combustion as the fuel and air enter the furnace. Higher furnace temperatures inevitably result from preheated air. It is only the damaging effect of the ash from coal that necessitates the reduction of furnace temperatures to a point where excessive maintenance cost and ash-handling difficulties do not offset the value of the hot furnace. This is borne out in the case of oil-fired furnaces where very high furnace temperatures are desired and attained, even to the point of melting high-grade firebrick.

In the entire history of burning coal the development has been along the lines of keeping the furnace walls and furnace bottom at a temperature below the fusing point of the ash in the coal being burned. The most generally used method of limiting the furnace temperature is by excess air, as the author[3] brought out in a previous paper. Excess air is usually admitted in certain parts of the furnace where otherwise clinker trouble would be most pronounced. This is a very effective remedy up to a certain point, but where the rates of combustion are too high for a given ash the percentage of excess air is likely to become excessive, and therefore interfere with the major requirement of complete combustion with a minimum of excess air. The tendency today, therefore, is to use water-cooling tubes, tied in as part of the circulating system of the boiler, to effect the cooling in different parts of the furnace wall or floors as needed. The nature and extent of such water cooling should be chosen with discretion, especially if the boiler is to be controlled with best efficiency and smokeless combustion is to be obtained over any reasonable range of output.

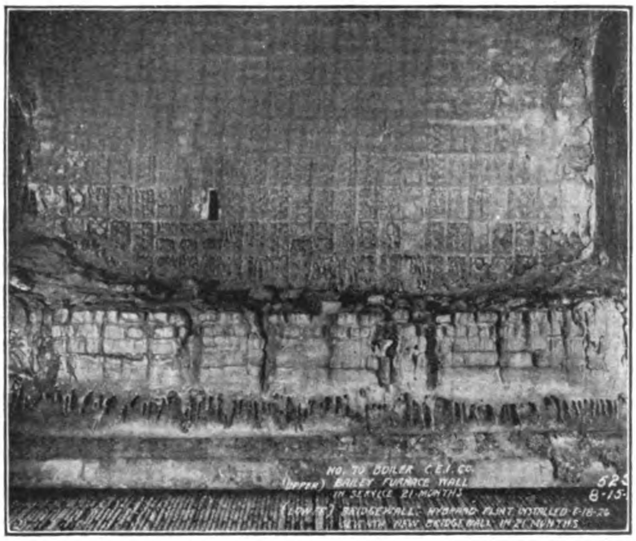
NO. 70 BOILER C.E.I. CO.
(UPPER) BAILEY FURNACE WALL
IN SERVICE 21 MONTHS
(LOWER) BRIDGEWALL: HYBRAND PLINT INSTALLED 6-18-26
SEVENTH NEW BRIDGEWALL IN 21 MONTHS
52
8-15-

FIG. 1—Furnace back wall, boiler No. 70, Lakeshore Station, showing action of molten slag from face of water-cooled wall (in service 21 months) over brick ledge (in service two months) on water boxes.

The second item of the foregoing list, namely, control of rate of combustion, is very important and excessive cooling of the furnace by either excess air or water circulation interferes with this result. The best performance can be obtained if the air supply can be controlled for proper combustion only, with the furnace as hot as possible, rather than supplying air for the dual purpose of cooling furnace walls and burning fuel. Air cooling, at best, is ineffective for high ratings when burning low-fusing ash.

The remaining three factors, namely, furnace-wall endurance, reduction of slag on boiler tubes, and re-

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[2] Bul. 135, U. S. Bureau of Mines, 1917, pp. 125-134.

[3] E. G. Bailey, Limiting Factors in Reducing Excess Air in Boiler Furnaces, Mechanical Engineering, July, 1926, p. 703.

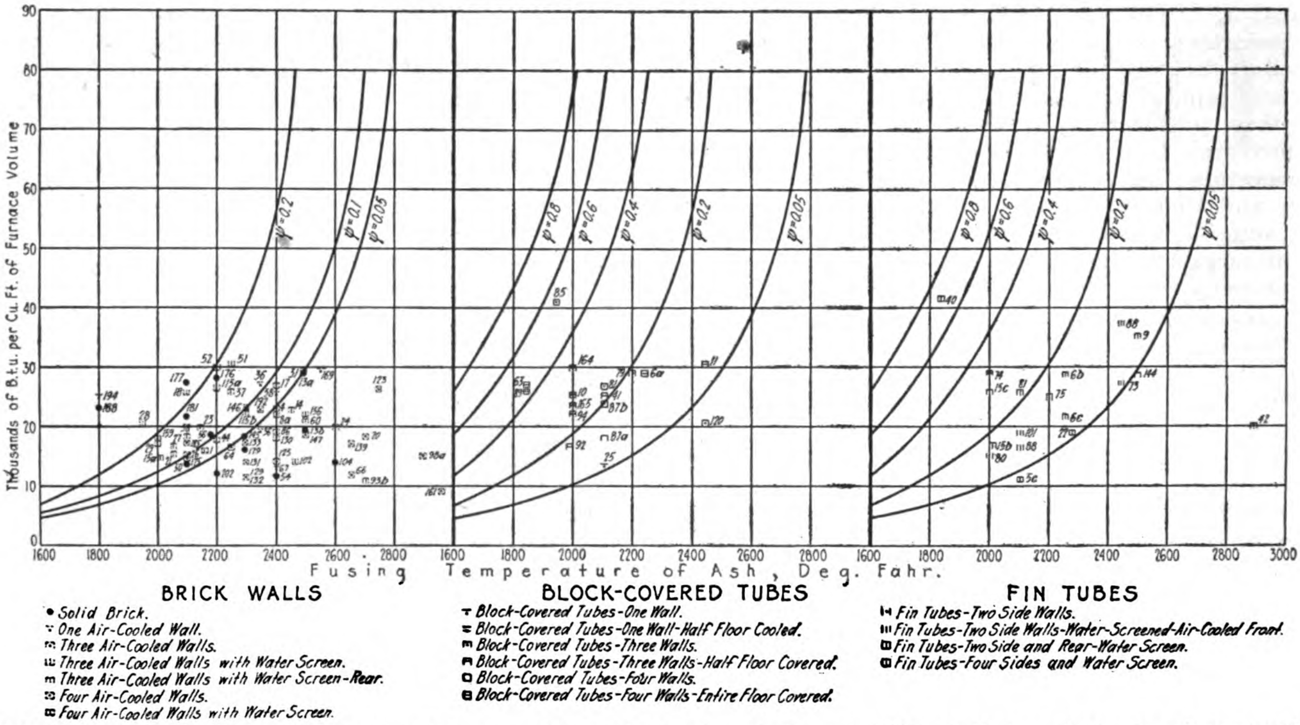

FIG. 2—Data from prime movers committee report on pulverized coal, August, 1927, plotted against rate of combustion and fusing point of ash, showing different kinds of furnace construction.

moval of ash from the furnace, are all closely associated, as they have to do with the molten condition of the ash in suspension in the furnace. This is a factor of major importance in pulverized-coal furnaces; and in modern stoker furnaces the fine particles of coke and ash that are carried up from the fuel bed are almost equally important. In either case there is an unlimited supply of ash available so that the quantity coming in contact with the walls is ample to destroy any wall in a comparatively short time unless the wall is protected by cooling it below the fusing point of the ash. While there is merit in using special qualities of refractory to resist the fluxing action of molten ash, only a limited benefit can be derived from this source, for sooner or later the ash will flux, or wash away any and all types of refractory if it is streaming over the refractory in a molten condition. Even in the case of oil there is sufficient ash of a comparatively low fusing temperature to waste away a brick wall in the course of time, but spalling or actual melting of the brick often destroys the walls quicker than fluxing and washing away by the ash from the oil.

The only positive manner of resisting the molten slag permanently is to reduce the temperature of the wall by absorbing heat at such a rate that a film of solidified slag will be maintained on it. Fig. 1 illustrates a furnace in which molten ash accumulates on a water-cooled wall and flows on to a ledge of refractory built on the waterback of a chain-grate stoker. The ledge has been in service for less than two months, and it is the seventh ledge to have been built in this furnace during the 21 months that the water-cooled wall had been in service when this photograph was taken.

The coal being burned has an ash fusing point of 2,100 deg. F. Many different kinds of brick were tried in this ledge, including alundum, carborundum, magnesite, chorme, and many brands of the best brick. Some of these resisted the slag longer than others, but in a comparatively short time they all eroded in substantially the same manner as is shown in this picture.

It seems that the importance of the fusing point of ash has not been fully realized in explaining why a furnace of a given design and arrangement gives satisfactory results when installed at one plant and proves quite unsatisfactory at another.

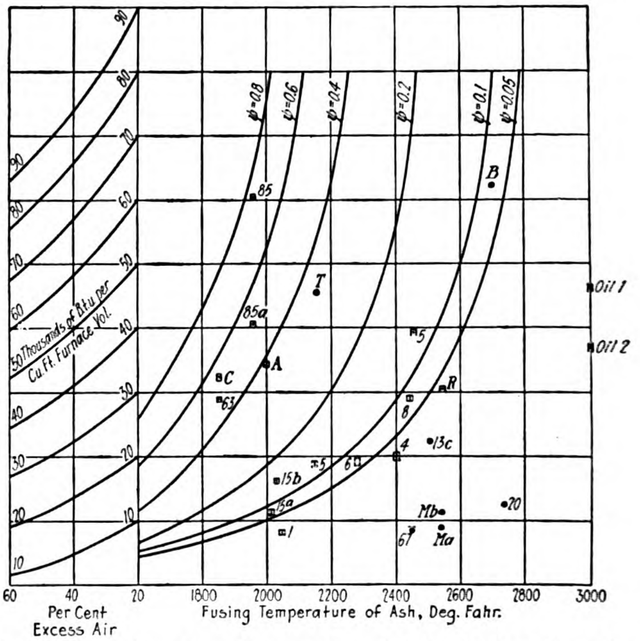

FIG. 3—Data from actual operation of pulverized-coal, stoker, and oil-fired furnaces similar to Fig. 2, but showing correction for excess air.

A recently published report of the Prime Movers Committee[4] gives a tabulation of essential data regard-

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[4] National Electric Light Association, Publication No. 267-95, "Pulverized Fuel," August, 1927.

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ing practically every pulverized-coal installation in this country. In Fig. 2 is plotted the "maximum combustion rate in Btu. liberated per cubic foot of furnace volume per hour," and the "fusing temperature of the ash" from all of the plants from which these data are listed. The types of furnace wall are divided into three major divisions: brick, block-covered tubes, and fin tubes. The plotted results show that while in general the water-cooled walls are designed for higher rates of combustion with coal having ash of a lower fusing temperature than the solid and air-cooled walls, many inconsistent data are being used as a basis for many of these designs. This is to be expected in this formative stage of the art.

It should also be remembered that these data largely represent the results that it was hoped would be obtained, which are often quite different from the actual results that are finally accepted as the practical operating limit.

To illustrate what is meant by the practical operating limit, let us suppose that a furnace has been built to burn 30,000 lb. coal per hour, equivalent to liberating 20,000 Btu. per cu. ft. of furnace volume per hour, when burning a certain coal. Let us also suppose that in designing the furnace a full realization of the limiting factors was not followed with the result that an air-cooled-refractory furnace was installed with perhaps some water cooling in the ashpit. When put into service it was found impossible to liberate more than 14,000 Btu. per cu. ft. per hour, and then only by the use of 35 per cent excess air, without causing a rapid deterioration of brickwork or an accumulation of ash and clinkers difficult to remove. The plant then is operated at this limited rating and efficiency, at which, in the judgment of the operating executives the sum of the maintenance, operating and fixed charges are at a minimum per unit production.

In Fig. 3 are also plotted data from a number of furnaces of various types of construction that represent fairly accurately the upper limit of rating as determined from experience in operation. This includes stoker and oil-fired furnace as well as pulverized-coal-fired furnaces.

In Figs. 2 and 3, the numbered points refer to the different plants as listed in the Prime Movers Report, starting with Table 1 and numbering the different plants consecutively through Table 2 of that report.

The curves labeled ψ represent the mean refractory temperature of the furnace walls with different rates of combustion for furnaces with different fractions cold, these values being taken from Wohlenberg and Brooks'[5] paper. It is assumed that the wall temperature is the same as the fusing temperature of ash.

A furnace with a fraction cold of 0.2 has 20 per cent of the entire furnace-wall area water cooled, including the boiler tubes exposed to the furnace as a cooled part of the furnace walls. With coal having an ash whose fusing temperature is 2,000 deg. F., a combustion rate of 18,000 Btu. per cu. ft. per hour. should be maintained and a combustion rate of 55,000 Btu. per cu. ft. per hour should be maintained with an ash having a fusing temperature of 2,400 deg. F., both with 20 per cent excess air.

Excess air has a cooling effect, and as it is desired to plot different furnaces on the same excess-air basis the correction factors are made in the form of curves at the left side of Fig. 3. To illustrate, if a furnace is liberating 30,000 Btu. per cu. ft. per hour with 40 per cent excess air it should be plotted on the horizontal position from the intersection of the 30,000 Btu curve with the vertical of line 40 per cent excess air, an equivalent of 23,000 Btu. per cu. ft. per hour with 20 per cent excess air.

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[5] W. J. Wohlenberg and F. W. Brooks, "Some Fundamental Considerations in the Design of Boiler Furnaces," paper presented at Tri-State Power Meeting of the Erie Section, A.S.M.E., Erie, Pa., June 3 and 4, 1927. Fig. 6.

TABLE 1

Ref. No.	Station	Heating surface, sq. ft.	Type	Burners	Fusing pt. ash deg. F.	Furnace volume, cu. ft.		Fraction cold	Excess air, per cent	Steam output, lb. per hr.	Heat liberation Btu. per cu. ft. per hr.	
						Total	Per cent below top of burner				For total furnace	For volume below top of burners
	Pulverized Coal											
67a	Trumbull Steel ..	5,000	Stirling	Flare	2400	4,637	33	0.150	32	46,500	12,200	37,000
Ma	Merrimac Chem. .	3,670	B&W	Flare	2500	1,711	70	0.127	40	16,600	14,000	20,000
Mb	Merrimac Chem. .	3,430	B&W	Turbulent	2500	2,745	65	0.127	40	20,700	17,100	26,100
13a	Narragansett	6,000	B&W long drum	Couch	2500	2,180	48	0.175	35	40,000	27,600	57,000
B	Bayonne	2,755		Turbulent	2700	255	54	0.200	38	13,706	75,062	139,000
63	Calumet No. 22 ..	5,938	B&W cross-drum	Calumet	1850	12,300	54	0.900	25	285,000	30,000	56,000
85a	Buffalo No. 15 ...	12,515	B&W cross-drum	Calumet	1950	10,200	17	0.820	18	275,000	40,450	234,000
85b	Buffalo No. 13 ...	12,515	B&W cross-drum	Calumet	1950	5,076	55	0.683	20	225,000	60,000	1,100 000
85b	Buffalo No. 13 ...	12 515	B&W cross-drum	Calumet	1950	5,076	55	0.683	20	150,000	40,000	750,000
15b	Cahokia	18,010	B&W cross-drum	Lopulco	2010	13,500	..	0.611	33	140,000	17,000	....
15a	Cahokia	18,010	B&W cross-drum	Lopulco	2010	11,750	..	0.395	33	110,000	14,000	....
6a	Colfax	27,680	B&W cross-drum	Lopulco	2250	17,050	..	0.465	32	320 705	21,800	....
20	Columbia Power .	15,110	B&W cross-drum	Vertical	2700	12,000	..	0.084	39	160,000	18,500	....
8b	Fordson	26,470	Ladd	Lopulco	2450	22,000	..	0.778	25	460,000	29,000	....
1	Lakeshore	30,600	Twin Stirling	Lopulco	2050	26,000	..	0.309	45	286,200	15,000	....
5b	Lakeside	17,500	Edge Moor	Lopulco	2100	12,040	..	0.310	22	150,000	17,000	....
4	Trenton Channel.	29,087	Stirling	Lopulco	2400+	25,140	..	0.371	25	392,000	22,270	....
	Stokers											
A	Aurora	10,010	B&W	Chain grate	2000	2,700	..	0.426	40	93,000	43,500	....
C	Crawford	16,220	B&W cross-drum	Chain grate	1950	5,577	..	0.623	34	157,905	38,000	....
R	Richmond	15,700	Stirling	Underfeed	2500	6,700	..	0.424	22	224,000	31,000	....
S	Saxton No. 5 ...	11,120	Stirling	Underfeed	2410	4,749	..	0.345	24	138,500	41,000	....
T	Twin Branch	14,086	B&W	Chain grate	2150	5,440	..	0.117	28	166,000	45,700	....
	Oil											
Oil	1 San Diego	10,940	B&W	B&W mech.	....	4,178	70.8	0.590	10	120,000	39,000	55,000
Oil	2 Long Beach ...	15,000	Connelly	B&W mech.	....	7,733	40.3	0.218	10	180,000	31,000	77,000

The same symbols are used in Fig. 3 as in Fig. 2 to represent the type of furnace construction. Table 1 gives the essential values used in plotting the points of Fig. 3 and some additional data of interest which will be referred to in describing briefly some of the furnaces.

It should be remembered that the data in Wohlenberg's paper are figured from a theoretical basis, assuming certain conditions as to the nature and cleanliness of the water cooling surfaces, uniformly distributed heat, etc., so that it is reasonable to expect that actual results plotted on a basis of this kind will deviate from the curves. There will also be limitations in furnace operation due to localized temperatures in the burner zone, or at the ash-removal point, that will cause the furnaces to be limited to a lower rate than would be required if the temperature could be uniformly distributed throughout the furnace. Therefore the deviation and the location of these points on the corresponding fraction-cold curve, or ψ curve, indicates the allowance which is found necessary for normal operation.

Fig. 4 represents the furnace installed at the Trumbull Steel Company, and is shown in Fig. 2 and 3, and Table 1 as point 67a. This furnace has no water cooling, and is air cooled only in the bridgewall, part of the secondary air entering here and flowing along the furnace floor. When burning coal with an ash having a fusing temperature of 2,400 deg. F. this furnace can operate at rates of combustion up to 12,200 Btu. per cu. ft. per hour with 32 per cent excess air, the brickwork having a satisfactory length of life and no serious trouble being experienced in ash removal, which is accomplished by scraping out the ashes from the flat-bottom floor through doors in the rear. This is equivalent to a rate of combustion of 9,000 Btu. per cu. ft. per hour on a basis of 20 per cent excess air, and is so plotted in Fig. 3. The inclined tubes of the Stirling boiler have some cooling effect on this entire furnace which has a ψ value of 0.150. It is noted from the curve that the maximum combustion obtained in practice is about one-fifth the rate of combustion shown on the corresponding ψ curve for ash of this fusing temperature.

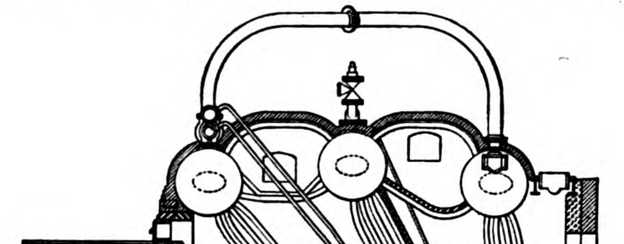

FIG. 4—Section of furnace at Trumbull Steel Company fired with pulverized coal, using five Fuller Lehigh Company flare burners. Reference 67a in Table I and Figs. 2 and 3.

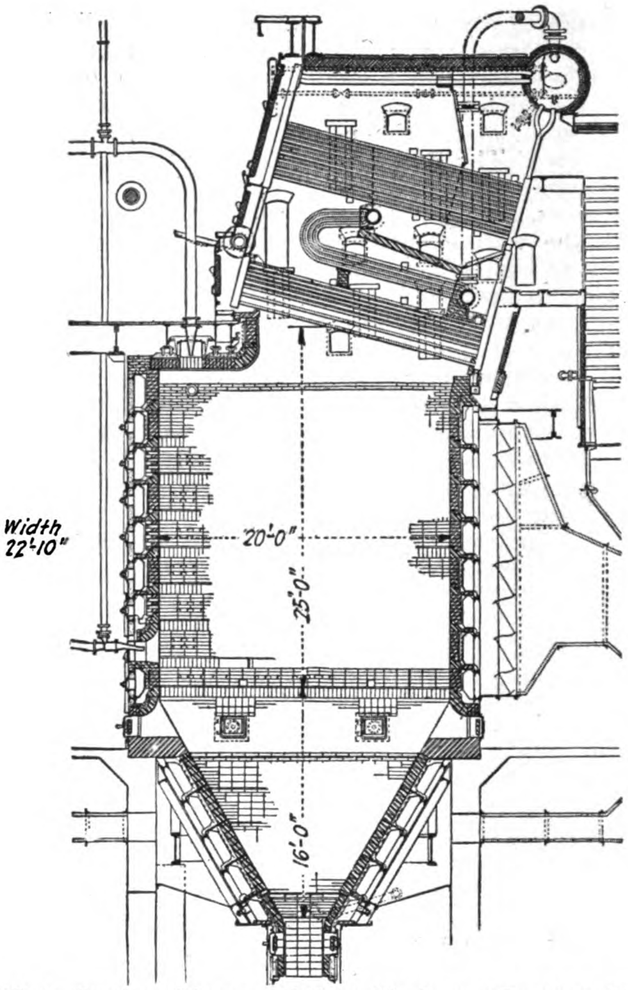

FIG. 5—Section of furnace of Columbia Power Company fired with pulverized coal, using nine vertical and six horizontal Fuller Lehigh flare burners. Reference 20 in Table I and Figs. 2 and 3.

Fig. 5 shows the furnace construction at the Columbia Power Company, which is designated in the figures and table as point 20. This furnace is very large, having both vertical and horizontal firing, and as only a small proportion of the total walls is exposed to the cooling action of the boiler tubes, the ψ value is 0.084. It is shown in Fig. 2 plotted against a fusing temperature of 2,700 deg. F and a combustion rate of 18.500 Btu. per cu. ft. per hour, while in Fig. 3 the excess air of 39 per cent brings the rate of combustion down to 13,000 Btu. per cu. ft. per hour on a basis of 20 per cent excess air. This is the upper limit for rate of combustion with this ash. Due to variations in coal supply the fusing temperature sometimes goes as low as 2,600 or 2,500 deg. F., in which case it is customary to increase still further the excess air and perhaps to operate at a lower rating. This point as

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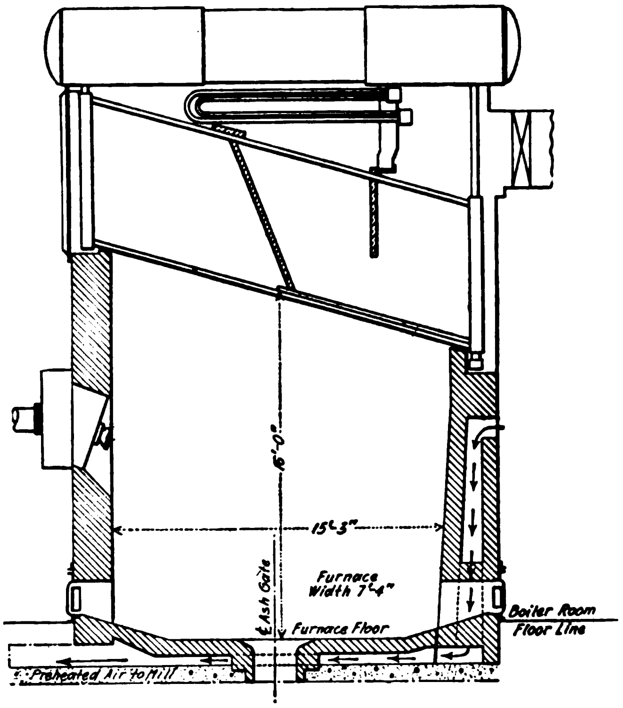


FIG. 6—Section of furnace at Merrimac Chemical Company fired with pulverized coal using one Bailey-Tenney turbulent burner. Reference Mb in Table I and Fig. 3.

plotted in Fig. 3 has a rate of combustion about one-fifth of what the ψ curve would indicate. In operating this type of furnace with too high a furnace temperature, the critical points are the removal of ash and the wastage of furnace walls near the burners. This plant has been in very satisfactory operation for almost two years, with a minimum of furnace maintenance cost, all of which is largely ascribed to the high fusing temperature of the ash in the coal being burned, and to the careful operation in keeping within the safe limits on rating and excess air.

Fig. 6 shows a furnace with a turbulent burner, no water cooling, and fraction cold of 0.127. With an ash fusing temperature of 2,500 deg. F., a rate of combustion of 17,100 Btu. per cu. ft. per hour is satisfactorily maintained. Another boiler in this same plant has a similar furnace, fired by a unit mill and with everything the same except the use of a flare-type non-turbulent burner. With this furnace it is difficult to get ratings as high as 14,000 Btu. per cu. ft. per hour, as compared with good operating conditions at rates over 17,000 Btu. per cu. ft. per hour with the turbulent burner, thus indicating a decided advantage in favor of the turbulent burner as relates to furnace-wall punishment.

Fig. 7 shows a 600-hp. longitudinal-drum B. & W. boiler, supplied with one Couch burner of the turbulent type, which is plotted as point 13c in Figs. 2 and 3. With an ash fusing temperature of 2,500 deg. F., this furnace operates at rates of combustion up to 27,600 Btu. per cu. ft. per hour with 35 per cent excess air, satisfactory life of furnace wall, and no serious difficulty with ash removal. It is believed that turbulence in burning, producing a transparent flame, aids in getting these results with ash of this fusing temperature.

(To be continued)

Large Water Softening System

Wm. B. Scaife & Sons Company have recently received an order from the Carnegie Steel Company for a water softening system for the Duquesne Works at Duquesne, Pa.

The softened water will be used for boiler feed and a total of 8,000,000 gal. per day will be the ultimate capacity; this amount of water will make it the largest complete water softening and filtration system ever installed for the treatment of boiler feed water.

The system will be of the Scaife We-Fu-Go Intermittent Type wherein the water will be treated and allowed time for reaction and sedimentation in four 540,000 gal. tanks. Each tank will be equipped with mechanical stirring devices for thoroughly mixing the reagents with the raw water to be softened; the tanks will also be equipped with indicating and recording gauges for recording the complete cycle of operation of each tank. After the water is softened it will pass through eight concrete filters, each of a capacity of 1,000,000 gallons per day.

The reaction-settling tanks will be equipped with electrically operated valves and the filters will be equipped with oil-pressure-operated valves of the hydraulic type. All filters will be equipped with indicating and recording loss of head gauges and indicating and recording rate of flow controllers.

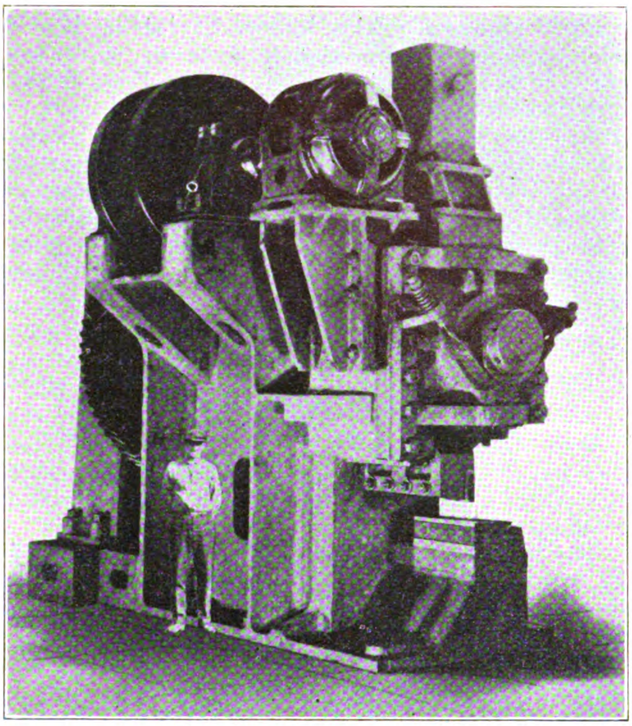
The water from the filters will be discharged into a clear well located under the pipe gallery and from which it will be delivered by special pumping equipment to an 800,000 gal. filtered water storage tank. The pumping equipment will be a novel arrangement in that it will be entirely automatically controlled so that the filtered water will be discharged to the filtered water storage tank or to the heaters as may be required without manipulation of valves.

An interesting feature of this system will be the fact that all valves are operated by remote control.

WITH THE EQUIPMENT MANUFACTURERS

Open Throat Shear

An improved type of open-throat shear of large capacity, capable of cutting 4½ in. square or 5 in. round cold alloy steel was recently designed and built by Mackintosh-Hemphill Company, Pittsburgh, Pa. This shear weighs about 225,000 lbs., and has a knife pressure of 1,400,000 lbs. Some idea of its size can be obtained from the fact that its total height measures about 16 ft. and the weight of the shear frame alone is over 40 tons. The shear has a stroke of 6½ in. and is designed to make about 15 cuts per minute. It is operated by a 125-hp. motor, located on top of the shear frame.



The drive gears are mounted on top of the shear which allows more floor space around the shear and keeps the motor and drive out of the way where it is less liable to injury.

All gears, including master gear and pinion, have herringbone cut teeth with a solid apex. The motor pinion and motor gear shaft are provided with ring oil bearings having babbitt lined shells fitted in steel bearing bases which are rigidly keyed and bolted to the shear frame. The fly wheels, as well as all gears, are enclosed in oil tight covers.

The pinion shaft is provided with two 63-in. fly wheels spaced symmetrically on the shaft which equalizes the load on the motor shaft bearings.

The eccentric shaft is provided with a square end on which the loose clutch slides. This shaft is supported in two bearings on the shear frame and by an out-board bearing at the clutch end and also one in the face plate. The eccentric is provided with a solid bronze slide which is mounted on the top ram. Bronze liners are also provided between the ram and the shear frame and the front side of the ram is equipped with an adjustable wedge for taking up any wear in the ram. The shear is provided with an air operated clutch which is also mounted on top of the frame.

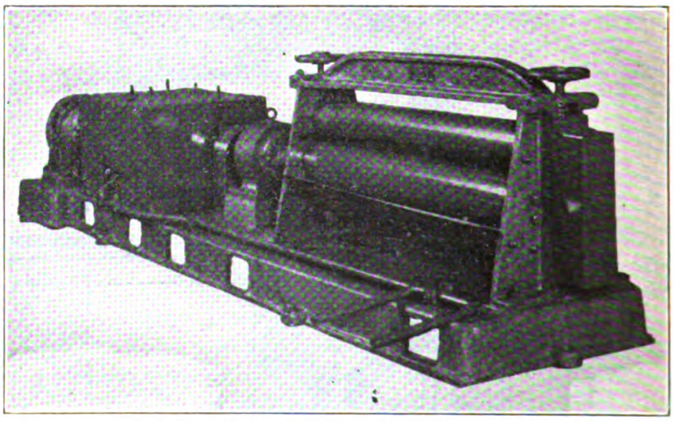
The top knife block is balanced by means of a double spring at the top of the shear which is easily accessible for adjustments or replacements. To insure the stopping of the top knife block in the upper position, a band brake is provided at the end of the eccentric shaft which automatically comes into action as the ram reaches the top of its stroke and goes out of action when the material is being cut.

The lubrication of this shear has been thoroughly analyzed and provisions have been made for supplying ample lubrication to all moving parts. While this shear is designed along the lines of its many predecessors, it has many decided improvements from the standpoint of operation and maintenance.

Sheet Pack Opener

The Aetna-Standard Engineering Company announce the addition to its line of a large Sheet Pack Opener.

Machines of this type have been operating for a number of years very successfully. The machine shown is a unit to handle large sheets, either on an angle when they are to be opened only on one corner, or run straight if the ends are to be opened clear across. These machines can be operated from either side; that is, a pack can be opened from either side of the machine. For instance, should a pack of six sheets be tightly stuck, it would be desirable to first open one sheet from the pack going one direction and another sheet from this pack going in the opposite direction. In this way there is no time lost in handling the pack from one side to another.



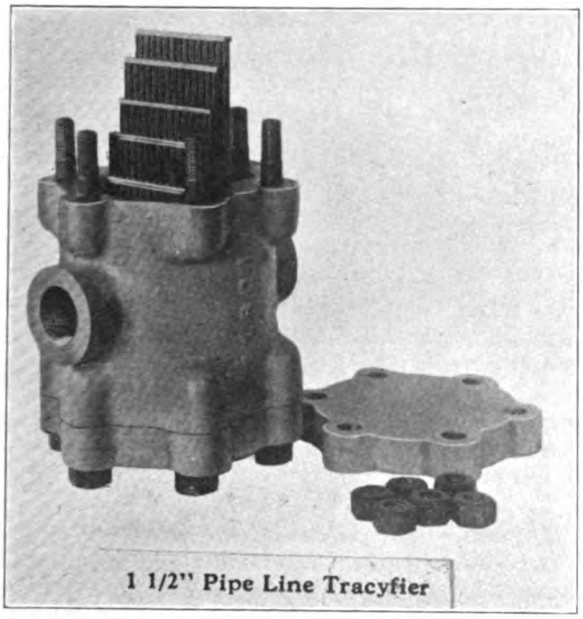
These units are portable and can be moved from one position to another as is most convenient to the pile of stickers, rather than the continuous handling of sheet piles from one point to another. The overall length of this unit is less than 17 ft. and the overall width 4 ft. The units can be operated with one operator and a helper.

For convenience in handling packs, a light roller table is provided on both sides of the machine. One company operating one of the smaller units on black tin plate sizes states that the machine paid for itself within two months.

Pipe Line Tracyfier

Using the same principles that have been so successful in the Tracyfier, this smaller purifier has been developed for use in several sizes of air, steam, or gas lines up to the 3 in.

In saturated steam lines it removes all moisture from the steam, delivering standard specification steam, which is free from all solids—both soluble and insoluble. Samples of condensed steam show no more than nine parts total solids per 1,000,000, which is the tolerance to cover dissolved copper and iron from the test condenser, unavoidable dust contamination during the collection of the sample and its evaporation and unavoidable errors in the laboratory determination of total solids. Standard specification steam is free from all moisture. Throttling calorimeter tests at all times show 100 per cent dry steam, plus or minus not more than .2 of 1 per cent, based on the determined normal of the calorimeter. The permitted variation of plus or minus .2 of 1 per cent is the tolerance for unavoidable variations in radiation and thermodynamic changes.


1 1/2" Pipe Line Tracyfier

Many uses are at once apparent for a "complete-separation" purifier of this size: In steam lines to gas producers to maintain a more uniform hydrogen content in the gas; in the steam lines leading to the tar burners on open-hearth furnaces, where the use of completely dried steam effects a three-fold purpose—it produces a shorter, hotter, more uniform flame, saves about a gallon of tar per ton of steel, and, most important, keeps the checker chambers far cleaner. Placed ahead of laundry or paper driers, the pipe line Tracyfier has been found to greatly increase the output of the machines.

These are but a few of the multitude of uses that are being found for this purifier in steam lines.

Perfectly clean air can now be obtained for use in air tools by the use of a pipe line Tracyfier in the air line near the tools—one pipe line Tracyfier will dry and clean the air for several tools. This results in a lowering of out-of-service time and an increase in output per tool.

Whenever a gas carries drops of liquid that it is desirable to remove, either for recovery, or elimination, the pipe line Tracyfier will accomplish perfect separation.

The pipe line Tracyfier is made and sold by Andrews-Bradshaw Company, a division of Blaw-Knox Company, Pittsburgh, Pa.

Worm Reduction Gear

The Fawcus Machine Company, of Pittsburgh, Pa., has recently placed on the market a new patented type of worm reduction gear especially designed to give ratios of speed reduction with better efficiency characteristics than are usually possible in worm gears where the ratios are so great. The units comprising the complete line, which is known under the type designation of W T H have been built in three sizes, Nos. 5, 6 and 7, with capacities of 15, 20 and 25 hp., with corresponding ratios of 98:1, 190:1 and 160:1, respectively. The actual speeds of the different units are, 900/4.4 rpm.; 1,150/6 rpm. and 1,150/7.2 rpm. The units have a common efficiency, about 75 per cent under the above load conditions. They are suitable for any sort of slow speed, heavy duty application that comes within the limit of their horsepower range. The horsepower ratios and speeds given are only illustrative, as the ratio can be varied up or down 50 to 300 to 1, with corresponding inverse horsepower variations.

The essentials in design and construction are uniform throughout the whole line, being substantially as follows: The driving motor is connected by means of a flexible coupling to a helical pinion which drives a helical gear mounted on an extension of the worm shaft. This gear drives the worm, which in turn drives the worm wheel. By this interposing the helical gear train between the motor and the worm shaft it is possible to hold the tooth angle on the latter within the limits that will give the best efficiency, and still obtain a high reduction ratio. Another feature that aids in obtaining a high degree of efficiency is the fact that all the various shafts are mounted in Timken bearings. The helical pinion shaft mounting comprises two bearings, one at each end of the shaft, and the same arrangement is used for the worm wheel. The worm shaft is mounted on two steep angle bearings, one located at the end opposite to the helical gear, and the other between the worm screw and the gear. The latter bearing has been selected as being of sufficient capacity to carry the overhanging load of the helical gear in addition to the normal loads imposed by the worm thrust.

The gear reduction unit and the driving motor are mounted on a heavy semi-steel unit base, provided with six lugs which permit its being firmly bolted to the floor, or foundation.

New Steam Operated Temperature Controller

The C. J. Tagliabue Manufacturing Company has brought out a new development in temperature controllers in which the regulating valve is steam operated. With this apparatus the equipment is independent of a compressed air supply source.

TRADE NOTES

The American Demag Corporation, an Illinois corporation with offices at No. 310 S. Michigan Avenue, Chicago, Ill., was formed on the first day of January 1928. This corporation was organized to sell the products of the Demag Company of Duisburg in the United States. The Demag Company of Duisburg, is the leading builder of steel plants, rolling mills, seamless tube mills, cold drawn machinery, harbor and dock equipment, etc. in Europe. They have also recently acquired the Thyssen Machine Company, builders of the heaviest mill machinery and the largest gas engines in the world. H. A. Brassert & Company, consulting engineers of Chicago are affiliated with the American Demag Corporation.

* * *

The Fusion Welding Corporation, 103rd Street and Torrence Avenue, Chicago, Ill., engineers, manufacturers and merchants, devoting their attention to both equipment and supplies as used in fusion welding and cutting, announce that they will shortly have full working exhibits, not only at their engineering laboratory in Chicago, but also at several cities scattered across the continent.

* * *

United Conveyor Corporation has purchased from Conveyors Corporation of America the good will, and all patterns, patents, designs and manufacturing rights for the American steam jet ash conveyor, the American cast iron storage tank and American air tight doors, and the steam jet ash conveyor business of its predecessors: American Steam Conveyor Corporation, Green Engineering Company, Girtanner-Daviess Company, Griffiin Engineering Company.

* * *

The Safe-T-Stat Company, Royce G. Martin, president, manufacturers of thermo-electric temperature indicators will move its Brooklyn, N. Y. plant to Toledo, Ohio, having purchased the W. G. Nagle Electric Company, Toledo.

* * *

At the annual meeting of the stockholders of the Pennsylvania Engineering Works held January 24, 1928, the following directors were elected: Lee E. Allen, A. B. Berger, O. P. Brown, T. A. Gilkey, Alex Crawford Hoyt, F. S. Hoyt, C. J. Kirk, W. H. Lewis, R. C. Patterson, H. G. Preston, and W. S. Wheeler. The following officers were elected: W. H. Lewis, president; W. S. Wheeler, vice president and treasurer; S. B. Cleal, secretary; Lee E. Allen, chief engineer.

* * *

Aerial Surveys, Inc., Fortieth and Perkins Streets, Cleveland, Ohio, is equipped to undertake the making of airplane maps and views of plants and their surroundings.

* * *

Fawell Engineering Company, Mr. Josepth E. Fawell, president, First National Bank Building, Pittsburgh, Pa., has been appointed exclusive representative in the Pittsburgh district for the Birdsboro Steel Foundry & Machine Company, Birdsboro, Pa., designers and builders of rolling mills, rolling mill machinery, hydraulic equipment and special machinery.

TRADE PUBLICATIONS

The Linde Air Products Company, 30 E. Forty-second Street, New York City, published a bulletin for free distribution entitled "Welded Piping" illustrating the many applications of welding to pipe fitting and plumbing jobs.

* * *

Centrifugal blowers and compressors as used in blast furnaces, steel plants and by-product coke oven plants are described, together with pumps, turbines and speed reducers, in bulletin E-1107, distributed by the De Laval Steam Turbine Company, Trenton, N. J. Centrifugal blowers and compressors are built with various numbers of stages, ranging from single stage blowers for blowing air through the fuel beds of water gas generators, to multistage compressors capable of supplying air at 100 lbs. pressure per sq. in. Centrifugal compressors are extensively used for exhausting gas from by-product coke ovens, and for boosting the pressure of gas for long distance transmission. De Laval centrifugal blowers and compressors are driven by De Laval steam turbines or by electric motors. Speed increasing gears are sometimes used in order to utilize standard speed motors.

* * *

A folder from The Electric Controller & Mfg. Company, Cleveland, Ohio features their new type S. A. lifting magnet and is entitled "Handling Hot Ingots" stressing the power of the magnet to lift slightly magnetic hot steel.

* * *

"Magnetic Protection" is the title of a new book just published by the Cutler-Hammer Manufacturing Company, Milwaukee, Wis., giving complete information on magnetic separator pulleys. The book explains in detail the construction and design of all types of separator pulleys. There are several helpful tables giving the cubic feet per hour capacity of all separator pulley sizes, and the correct width and thickness of the belts to be used.

The book is decidedly interesting in that it explains in detail the construction features which Cutler-Hammer maintains are absolutely necessary if unfailing, complete protection and continuous operation are to be assured.

The book will be a valuable addition to every superintendent's library. It will be sent free upon request to The Cutler-Hammer Manufacturing Company, 99 Twelfth Street, Milwaukee, Wis.

* * *

The Dry Quenching Equipment Corporation, International Combustion Building, 200 Madison Avenue, New York City, will send on request catalog DQ-2 entitled "The Sultzer System" describing the dry quenching of coke and its advantages with an economic analysis of the process.

* * *

"Rotary Car Dumpers" is the title of bulletin No. 103 of Roberts & Schaefer Company, 418 Oliver Building, Pittsburgh, Pa., describing the applications of this type of car dumper to mine and rock cars, etc., and the adaptability of solid body cars through its use.

A Prepared List of Books on Steel Plant Practice and Allied Subjects

Metallurgy of Steel
Harbourd and Hall

Vol. I. Seventh edition, thoroughly revised, 200 illustrations, 577 pages, 8vo., cloth. $12.00.

CONTENTS—The Manufacture of Steel—The Bessemer Process; The Basic Process; Manufacture of Steel in Small Converters; Chemistry of the Acid Bessemer Process; Chemistry of the Basic Bessemer Process; Gas Producers; The Open Hearth or Siemens Process; Basic Siemens Process; The Production of Steel Castings; The Production of Shear and Crucible Steel; Production of Steel in the Electric Furnace; Armor Plate Manufacture; Direct Processes of Steel Manufacture. Finished Steel—Mechanical Testing of Materials; Carbon and Iron; The Influence of Si, S, P, Mn, As, Cu, Sn, Sb, etc., on the Physical Properties of Steel; Special Steels or Steel Alloys; Heat Treatment of Steel; Microscopical Examinations of Steel; Typical Steel Plants; Photomicrographs. Appendices.

The Metallography and Heat-Treatment of Iron and Steel
Sauveur

By Albert Sauveur, Gordon McKay Professor of Metallurgy and Metallography in Harvard University. 535 pages, 7x10, 463 illustrations. $8.00.

The standard treatise on the subject. It presents in a scientific and practical manner a well-balanced, specific and comprehensive treatment, covering the structure of metals, the processes, manipulation and apparatus used successfully in the author's own laboratory and in the laboratories of other workers.

The present edition includes descriptions and discussions of the notable advances in metallography during the last decade. Every chapter has been revised and enlarged and several practically rewritten. Much new material has been added as well as some 125 illustrations. M

Analysis of Fuel, Gas, Water and Lubricants
Parr

By S. W. Parr, Professor of Applied Chemistry, Universty of Illinois. International Chemical Series. Third edition. 250 pages, 5½x8, 54 illustrations. $2.50.

CONTENTS—Part I, Lectures. Fuels; Coal; Sampling of Coal; Analysis of Coal; Unit Coal; Calorimetric Measurements; Ultimate Analysis; Classification of Coals; Coal Contracts; Combustion of Coal; Storage, Weathering and Spontaneous Combustion; Coke; Wood; Petroleum, Distillates and Alcohol; Fuel Gas; Flue Gases; Boiler Water; Lubricants. Part II, Laboratory Methods. Proximate Analysis of Coal; Calorimeter, Using Sodium Peroxide; Calorimeter, Using the Oxygen Bomb; Sulphur Determinations; Ultimate Analysis; Fuel Gases Analysis; Analysis of Flue Gases; Analysis of Boiler Waters; Oil Examination. M

Strength of Materials
Poorman

313 pages, 6x9, 211 illustrations. $3.00. In this new book Professor Poorman's ability to appreciate the student's difficulties and to simplify and clarify the explanations of abstruse points is again apparent. Throughout the work a large number of illustrative examples have been worked out in detail to aid the student in mastering the relation between theory and application. The book offers a well-balanced, vigorous text.

CONTENTS—Elastic Stresses and Deformations; Tension and Compression; Ultimate Stresses and Deformations: Tension and Compression; Shearing Stresses and Deformations; Riveted Joints; Shear and Moment in Beams; Stresses in Beams; Deflection of Cantilever and Simple Beams; Fixed and Continuous Beams; Beams of Constant Strength; Beams of Two Materials; Resilience in Beams; Torsion of Shafts; Combined Stresses; Suler's Column Formula; Rankin's Column Formula; Straight Line Column Formula; Column in General; Deflection of Beams by Area Moment Method; Deflection of Beams by Equivalent Cantilever Method; Curved Beams and Hooks.

Standard Handbook for Electrical Engineers
Fowle

Editor-in-chief, Frank F. Fowle, Consulting Engineer, assisted by a staff of more than 60 specialists. Fifth edition, completely revised and enlarged. Total issue, 88,500. 2100 pages, 4½x7, flexible, thumb-indexed, illustrated. $6.00.

The widely known encyclopedia of electrical engineering is thoroughly revised to embody the latest developments and data. Some of the sections have been entirely rewritten. All have been brought strictly up to date. The book covers every branch of modern electrical engineering. It is complete and reliable, and so carefully and fully indexed that its information is readily accessible. M

Materials Testings—Theory and Practice
Cowdrey and Adams

By Irving H. Cowdrey, Assistant Professor of Testing Materials, and Ralph G. Adams, Instructor in Mechanical Engineering, Massachusetts Institute of Technology. 129 pages, 6x9, 51 illustrations, cloth. $1.50.

This book gives a concise presentation of the methods and the fundamental theory of the testing of materials of construction, with condensed specifications and properties of the more common ones. A study of the test will lead to a clearer understanding of specifications, and will be of assistance in the interpretation of the results of physical tests.

CONTENTS—Province of the Testing Engineer. The Report. Testing Machines. Tensile Tests. Graphs. Compressive Tests. Torsional Tests. Transverse Tests. Dynamic Tests. Test Specimens and Holders. Fractures and Their Significance. Hardness Determination. Cement Testing. Testing of Sand. Timber Testing. Measuring Devices. Verification of Testing Machines. Appendix.

Microscopic Analysis of Metals
Osmond and Stead

Third edition, revised and corrected by L. P. Sidney. 313 pages, 8vo., cloth. $4.50.

The new edition of this extremely valuable book is now in preparation and comprises features which render it thoroughly up to date in every respect. It is very beautifully illustrated with 195 photomicrographs, diagrams and figures and covers such important subjects as Anatomical Metallography, Biological Metallography, and Pathological Metallography, also the Science of Polishing, Grinding, etc., the Micrographic Analysis of Carbon Steels, the Micrographic Identification of the Primary Constituents of Carbon Steels, the Detailed Examination of Selected Steels, the Segregation in Steel and the Phenomena of Burning, Overheating, etc.

Industrial Furnaces—Principles and Furnace Calculations
Trinks

By W. Trinks, M.E., Consulting Engineer, Professor of Mechanical Engineering, Head of Department of Mechanical Engineering, Carnegie Institute of Technology. Vol. I. 319 pages, 6x9, 255 figures. Cloth, $4.50.

The volume deals with the principles which underlie all industrial heating operations and all furnace design. It is a carefully prepared and thorough treatment, based on an extensive experience.

CONTENTS—Introduction; Heating Capacity of Furnaces; Fuel Economy of Furnaces; Heat-Saving Appliances in Combustion Furnaces; Strength and Durability of Furnaces; Movement of Gases in Furnaces. W

The Manufacture of Electric Steel
Sisco

By Frank T. Sisco, Chemist and Metallurgist. 304 pages, 6x9, 44 illustrations. $3.00.

A complete, practical description of the manufacture of electric steel, discussing both acid and basic processes and the chemical reactions involved. The book deals with the practical operation of electric furnaces and the actual making of a heat of steel.

CONTENTS—Electric Steel, Its Past, Present and Future; Materials Used in the Electric Process; Electric Arc Furnaces—General Considerations; The Heroult Furnace; Other Direct Arc Furnaces; The Cold Scrap Process—General Melting Practice; The Chemistry of the Basic Electric Process; The Cold Scrap Process—Variations in Melting Practice; The Manufacture of Special Steels by the Cold Scrap Process; The Hote Metal Process; Electric Steel Pouring Practice; The Characteristics of Basic Electric Steel; Acid-Melting Practice. M

Modern Open Hearth Plant
Hermanns

Diagrams, tables, 7x10, cloth, 307 pages. $10.00.

This is a book on the one hand for the steel works staff and managers, on the other hand for technical and higher grade students.

The book opens with a short history of the Siemens-Martin process, and after outlining the metallurgical theory, consideration is given to the layout of steel works and the detailed examination of the work which each section has to perform Numerous plans point the moral and emphasize the difference between good and bad practice, for the question of economy in transport is intimately involved.

Those concerned with the design and working of melting furnaces will find here invaluable data and comparison. Important sections on producers, charging machines, crane arrangements, waste-heat boilers and all those secondary improvements which can determine the balance between profit and loss, follow.

CONTENTS—Introduction: Historical and Statistical Data on the Open Hearth Process. The Metallurgical Principles of the Open Hearth Process. The Location of the Steel Works in Relation to Other Plant; Supply of Raw Material; Supply of Liquid Iron; Provision of Heat; Removal of the Products; Railway Sidings. Relative Location of the Individual Departments: Raw Material and Furnace Material Stores; Transverse Sections of the Open Hearth Steel Works; Various Bays of the Steel Works. Details of Equipment; Buildings; Furnaces; Gas Producers; Auxiliary Machinery. Arrangements and Efforts to Improve the Thermal Efficiency of Open Hearth Steel Works: Recovery of Tar from the Gasification Plant; Application of Richer Gases; Waste Heat Boilers; Supervision of the Thermal Efficiency. The Duplex and Triplex Processes—Present Applications and Prospects. Bibliography. Index.

Send order and remittance to STEEL PUBLICATIONS INC., Box 65, Pittsburgh, Pa.

NEWS OF THE PLANTS

The Shea-Whelpley Construction Company of Cleveland has been awarded the contract for the erection of a 25 ft. x 30 ft. Morgan heating furnace at the Cuyahoga Works plant of the American Steel & Wire Company, Cleveland.

* * *

Otis Steel Company, Cleveland, Ohio, plans the addition of three open-hearth furnaces, one of which with a capacity of 125 tons will be built this year. With the present equipment of five furnaces the ingot capacity is insufficient to meet the needs of the mills.

* * *

Wycoff Drawn Steel Company with plant at Ambridge, Pa., has acquired the Fitzsimmons Steel & Iron Company, Chicago. The combination makes this company one of the three largest producers of cold finished steel.

* * *

The Weirton Steel Company, Weirton, W. Va., has recently completed and lighted up a new open-hearth furnace with a capacity of 250 tons per heat. The new furnace brings the total open-hearth units to eleven.

* * *

American Steel & Wire Company plans improvements estimated at $5,000,000 including a new rod mill for the Cuyahoga Works.

* * *

The stack of the Gulf States Steel Company, Alabama City, Ala., is to be rebuilt with a view particularly to reducing the amount of flue dust blown over into the dust catcher.

* * *

Sloss-Sheffield Steel & Iron Company, Birmingham, Ala., is rebuilding the No. 1 city furnace along modern lines.

* * *

American Sheet & Tin Plate Company is replacing the sheet furnaces at the Gary, Ind., hot mill division with new units, the work being done by Rust Engineering Company, Pittsburgh.

* * *

Geo. N. Hold, chairman of the blast furnace committee of the Bethlehem Steel Company has been making an inspection of the furnace practice at the Sloss-Sheffield Steel & Iron Company, Gulf States Steel Company, Tennessee Coal, Iron & Railroad Company, Woodward Iron Company and others. The equipment devised by J. P. Dovel, vice president of the Sloss-Sheffield Company to minimize flue dust was included in his studies.

* * *

The Corrigan, McKinney Steel Company of Cleveland, has relighted one of its furnaces that was out for relining, and has blown out another for relining, continuing with three of its furnaces active.

* * *

Steel & Tubes Inc., will build a continuous hot strip mill at its Elyria, Ohio, plant. The new mill will roll strips up to 14 in. wide and will cost about $1,500,000. Construction will be started in about six months and when in production the mill will employ about 150 men.

The Wheeling Steel Corporation sent out its steamer, Transporter, from the Portsmouth works with a tow of steel for Memphis, delivery including 12,000 kegs of nails, 3,500 spools barbed wire and 600 rolls of wire and some sheet-plate.

* * *

Hanging Rock Furnace near Ironton, Ohio, one of the historic stacks in the district, abandoned in 1923 is being dismantled and scrapped.

* * *

The Jones & Laughlin Steel Corporation completed the loading of its sixty-first tow with steel at the Aliquippa works, consisting of six steel barges consigned to Memphis and Cincinnati. Two of the barges carry sulphate of ammonia to be reconsigned at Memphis for agricultural uses in the south west.

* * *

Notice in the daily papers giving an account of a fire in the Midland plant, Mackintosh-Hemphill Company, Midland, Pa., placing the amount of the damage resulting from the fire as $5,000; but this was in error, as the actual damage was very slight and the fire was easily extinguished with a hand extinguisher.

COMING MEETINGS

March 19-21—Concrete Reinforcing Steel Institute. Fourth annual meeting, Edgewater Gulf Hotel, Biloxi, Miss. M. A. Beeman, Tribune Tower, Chicago, is secretary.

* * *

April 3-5—American Oil Burner Association. Fifth annual convention and exposition at Hotel Stevens, Chicago. Leod D. Becker, 350 Madison Avenue, New York, executive secretary.

* * *

April 5-6—Indiana Fuel Conference at Purdue University, Lafayette, Ind. Engineering Extension Department, Purdue University.

* * *

April 23—American Welding Society. Annual meeting at New York. M. M. Kelly, 33 West Thirty ninth Street, secretary.

* * *

April 25-26—National Metal Trades Association. Thirtieth annual meeting at Hotel Astor, New York. J. E. Nyham, secretary, People's Gas Building, Chicago.

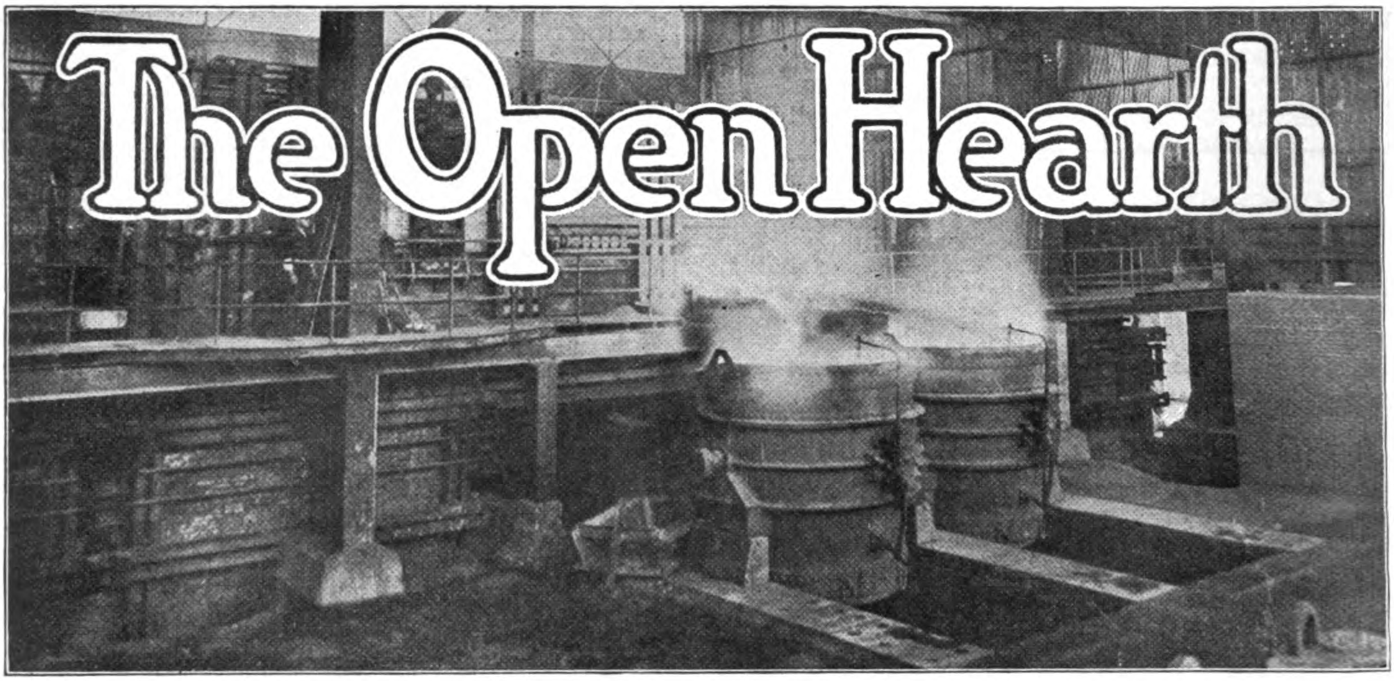
* * *

April 25-27—National Foreign Trade Council. Fifteenth anniversary convention, Houston, Tex. O. K Davis, secretary, 11 Park Place, New York.

* * *

April 26-28—American Electrochemical Society. Spring meeting at Hotel Stratfield, Bridgeport, Conn. Dr. Colin G. Fink, Columbia University, New York City, is secretary.

The Open Hearth



George H. Charls, who since May 1927 has been commissioner of the Hot Rolled Strip Steel Institute, has been chosen president of the newly organized National Association of Flat Rolled Steel Manufacturers. Mr. Charls was for 17 years in the sales department of the American Rolling Mill Company, and had advanced to the position of vice president in charge of sales when, in 1918, he resigned to accept the vice presidency and general managership of the Stark Rolling Mill Company and the Berger Manufacturing Company, of Canton, Ohio. In 1921 on the consolidation of these two companies with the United Alloy Steel Corporation, Mr. Charls again assumed the position of vice president and general manager. He later became president of the United Alloy Steel Corporation in which capacity he served until 1926 when this corporation was merged with the Central Steel Company of Massillon, Ohio.

* * *

R. L. Spencer was made chief engineer of the McAleenan Corporation, Pittsburgh, Pa., manufacturers of water tube boilers. Mr. Spencer was formerly connected with the Heine Boiler Company, International Combustion Corporation.

* * *

Jack T. Richards has been appointed superintendent of the hot mills of the Weirton Steel Company, succeeding Walter Kaiser. The department includes 26 mills all working steadily. Mr. Richards had been foreman in the department and has been with the company 16 years.

* * *

John W. Halloran, formerly with the Sharpsville Furnace Company, has been made assistant superintendent of the blast furnaces of Witherbee Sherman & Company, Port Henry, N. Y.

* * *

J. B. McComb, vice president of the Crucible Steel Company of America, and who has been a member of the board, assistant treasurer and secretary of the Motor and Accessory Manufacturers' Association, has been elected president of the association.

* * *

Dennis K. Bartlett has retired as service manager and yard superintendent of the Clinton, Mass., plant of the Wickwire Spencer Company. Theodore W. Jewett becomes service manager and Michael Lynch yard superintendent.

* * *

William C. Oberg has been chosen to fill the new post of superintendent of roll departments of the Carnegie Steel Company, with headquarters at the company's general office in Pittsburgh. He had been for nine years superintendent of the roll department, Homestead Works.

* * *

Dr. Thomas S. Baker, president Carnegie Institute of Technology, Pittsburgh, will spend February and March in Europe in the interests of the organization of the second International Conference on Bituminous Coal which will be scheduled for the week of November 29.

* * *

C. H. Heist has been made general manager of the Mayville Iron Company plant, Mayville, Wis. He succeeds J. H. Means.

* * *

Fred J. MacMackin, secretary-treasurer of the Andrews Iron & Steel Corporation, Utica, N. Y., has been appointed general manager.

* * *

John S. Brooks, Jr. was elected a director of the Pittsburgh Steel Foundries Company, succeeding John B. Black.

* * *

James A. Henry is general manager of strip sheet sales for the Weirton Steel Company, Weirton, W. Va., succeeding Joseph F. Savage.

The Open Hearth

F. Wallace McKaig, formerly vice president and general manager of the Cumberland Steel Company, Cumberland, Md., succeeds his father, the late Merwin McKaig, as president of the company. He retains his post as general manager and Z. M. Hewitt has been made vice president. Guy J. Spear becomes treasurer.

* * *

Announcement of five promotions among the executive staff of the manufacturing department of the Westinghouse Electric & Mfg. Company has been made by Mr. H. P. Davis, vice president. Mr. W. J. Longmore has been transferred from the office of general purchasing agent to consulting supervisor of purchases; Mr. E. R. Norris, from director of works equipment to general works manager of all manufacturing operations; Mr. A. W. Bass, from director of works records and statistics to assistant to the vice president; Mr. S. E. Marks, from director of traffic and shipping to director of traffic; and Mr. C. G. Taylor from director of purchases to general purchasing agent.

* * *

Dana Summers has been selected as general superintendent of the Chicago Steel & Wire Company, Chicago. He has been connected with the making of wire for 15 years.

* * *

William C. Potter, president of the Guaranty Trust Company, New York, succeeds Harold Stanley, resigned, as a director of the Bethlehem Steel Corporation, Bethlehem, Pa.

* * *

Appointment of W. R. G. Baker as managing engineer of the radio department of the General Electric Company, effective February 1, is announced by C. C. Chesney and E. W. Allen, vice presidents. Mr. Baker succeeds Adam Stein, Jr., who has joined the executive staff of Acoustics Products Company, a holding company recently organized to take over a number of radio phonograph companies.

Mr. Baker has been connected with radio development of the General Electric Company, since the company became active in this field and his progress in the organization has kept pace with the development of the art.

* * *

H. H. Morgan has been made metallurgical engineer in charge of the rail and track fastening department of Robert W. Hunt Company, engineers, Chicago, succeeding C. W. Gennet, Jr. Mr. Morgan has been with the company since 1904. Mr. Gennet resigned to become associated with the Sperry Development Company.

* * *

Harold P. Ingram succeeds W. C. Oberg as superintendent of the roll department, Homestead Works, of the Carnegie Steel Company.

* * *

John H. Watson, Jr., is the new president of the Corrigan-McKinney Steel Company, Cleveland, Ohio. Mr. Watson had been for many years the personal attorney of the late James W. Corrigan and was secretary and general council for the company. J. E. Ferris was elected to fill the post of secretary thus left vacant. The company will continue to operate as an independent.

* * *

E. J. Schuler has been added to the staff of engineers of the Fusion Welding Corporation, Chicago. He was formerly in charge of welding for the New Orleans Public Service Corporation.

* * *

C. W. Heppenstall, president Heppenstall Forge & Knife Company, Pittsburgh, celebrated the 35 year of his connection with the company entertaining the officers and veteran employees at a banquet February 11. Mr. Heppenstall began his career as office boy for the company which was then known as the Tretheway Company.

* * *

Mr. Geo. L. Elliott formerly with Glenfire Steel Company, of Youngstown, Ohio, in the waterproofing department, has recently become connected with the Celite Products Company, Pittsburgh, promoting the sale of Celite in concrete.

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THE STEEL PLANT ROLL TURNER AND DESIGNER

The inclusion in this issue of Blast Furnace and Steel Plant of a page for the Steel Plant Roll Turner and Designer is further evidence of the desire of the publishers of this magazine to give recognition to a branch of the industry little noticed. This page will be a permanent feature henceforth.

Rolling Variations in Producing Round Bars

The rolling of round bars, as accomplished in the average mill, is not very accurate either as to "size" or "out of round" limits. As the round shape is produced in the last pass in a round groove from an oval out of the preceding pass, three definite maladjustments are possible. First, the oval may be of greater or less area than is correct to fill the pass; if too large it will over fill or fin, and if too small the finished bar will flat. In the second place, the finishing pass may be set too full or too scant so that the vertical dimension of the bar is off. In the third place, and frequently overlooked, the rolls may not be adjusted horizontally so that the groove is "crossed," in which case the bar will leave a high "shoulder" and a low "shoulder" and lop sided.

While these defects are not hard to locate and the shape can be inspected without any particular delay, the full corrections are difficult to maintain as the variations in heating, wear on the roll neck brasses, and the personal judgment of the roller all have an influence. For this reason specifications have been kept somewhat liberal in spite of various exacting requirements of the trade for rivet and bolt steel and bars for cold heading to accommodate the grips of automatic machines and the rolling of threads.

Another feature that is met with in certain classes of exacting trade, particularly the bolt trade, is the odd size question. The mill may not leave a groove and tries to get the item out on some groove near to the size wanted. This of course makes the variation in section greater in one direction, or in other words, the size made is more like that of the groove than like that aimed at. In rolling to accuracy the groove used must be exact. Bolt manufacturers particularly have had too many sizes and should standardize on the practice with regards to sizes so that the number of grooves necessary are a minimum.

A. S. T. M. Permissible Variations in the Size of Bars. Hot Rolled Bars.

Rounds, squares and hexagons: Sizes specified	Variations in size, inches Under	Over
Up to ½ in., inclusive	0.007	0.007
Over ½ to 1 in., inclusive	0.010	0.010
Over 1 to 2 in., inclusive	1/64	1/32
Over 2 to 3 in., inclusive	1/32	3/64
Over 3 to 5 in., inclusive	1/32	3/32
Over 5 to 8 in., inclusive	1/16	⅛

Several devices as adjuncts to the mill have been developed—sizing mills or stands that improve the shape and uniformity of the bars. Certain mills by careful heating and rolling practice accomplish especially good results. Claims made, however, are usually somewhat exaggerated.

The regular published tables of size variations are as close as the ordinary mill can roll, in fact in regular practice a percentage of the bars furnished run outside. The practice of sorting to set gauges "go and not go" is necessary for many items where the requirement is exacting and must be absolutely met.

Walter H. Pfeil has been appointed roll foundry superintendent by the Birdsboro Steel Foundry & Machine Company of Birdsboro, Pa. Mr. Pfeil being a native of Pittsburgh has devoted the greater part of his life with the steel trade in the capacity of metallurgical engineer. His education dates back to the Colorado School of Mines and Carnegie Institute of Technology where he made a thorough study of metallurgy. Mr. Pfeil has made several trips to Europe in connection with research work in his studies. His early experience in the roll business starts with the Lewis Foundry & Machine Company, of Pittsburgh, later built the roll department at Standard Engineering Company, Ellwood City, Pa., being with this concern for a period of five years. Two years with Farrel Foundry & Machine Company, of Ansonia, Conn., as metallurgist, followed by seven years with Hubbard Steel Foundry, East Chicago, Ind., as chief metallurgist and roll foundry superintendent.

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THE STEEL PLANT BRICK MASON

L. J. Trostel Elected Chairman Refractories Division American Ceramic Society

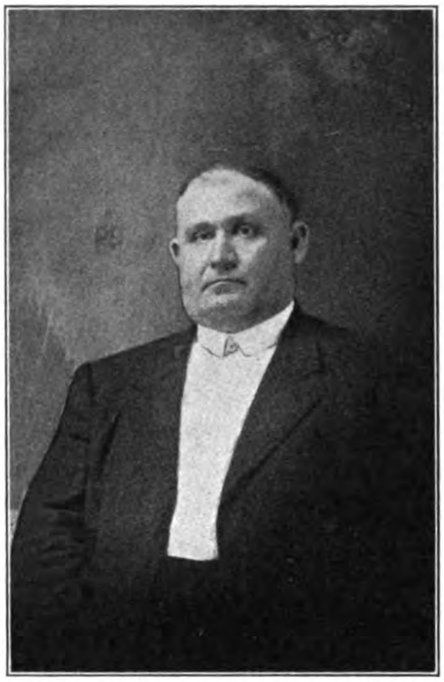
Graduated in chemical engineering from Ohio State University 1918. During the war served as steel examiner on the technical staff of the British Ministry of Munitions in the Pittsburgh and Birmingham districts.

Following the war spent three years on various research projects with the U. S. Bureau of Mines and the Bureau of Chemistry, stationed first in Pittsburgh and later in Washington, D. C.

During the past five years served as chief chemist for the General Refractories Company with headquarters at the research laboratories of the company at Baltimore, Md.

Elected chairman of the refractories division of the American Ceramic Society at the annual meeting in Atlantic City, February 1928. Also a member of the research advisory committee of the American Refractories Institute; secretary of committee C-8 on refractories of the American Society for Testing Materials; a member of the joint committee on foundry refractories sponsored by the leading engineering and technical societies of this country; and a member of the American Chemical Society.

L. C. Hewitt, ceramic engineer in charge of research at the Laclede-Christy Clay Products Company, St. Louis, presided over meetings of the society. Besides the chairman, Louis J. Trostel, officers elected at the business session were: vice chairman, E. H. Van Schoick, Chicago Retort & Fire Brick Company, Chicago; and secretary-treasurer, C. F. Geiger, Carborundum Company, Perth Amboy, N. J.



Mr. J. F. Grostloss has charge of the brick masons at the Mingo Works of the Carnegie Steel Company, Mingo Junction, Ohio, where he has been for many years. When not employed at his duties Mr. Grostloss can be found with gun or rod.

Annual Meeting of Refractories Institute

The directors of the American Refractories Institute have selected White Sulphur Springs, W. Va., as the place for the annual meeting to be held on May 8 and 9. Information concerning this meeting may be obtained from the secretary of the Institute, 2202 Oliver Building, Pittsburgh, Pa.

Causes of Spalling

When any dimensional change takes place due to expansion, or when dimensional irregularities exist in the shape of the brick, spalling takes place either due to the internal strains on the material due to the changes or to strains imposed by outside pressure.

Silica Brick

Silica brick are made from rock containing from 97 to 98 per cent SiO_2. They are almost invariably bonded with 2 per cent of lime and given a sufficient heat treatment to bring about inversion of nearly all of the quartz to cristobalite and tridymite. Silica brick from the roofs of open-hearth furnaces have been examined after campaigns of various lengths by a number of investigators who have found that the brick, after use, contain several unlike zones. At the cooler end the brick remain in their original state, while at the hot ends the lime and alumina are lower and the iron oxide higher than in the brick as originally installed. In the intermediate zones the contents of lime, alumina and iron are all higher than in the original brick. This means that the impurities or fluxes have migrated from the hottest to the cooler portions of the brick, and if it were not for the abnormal concentration of iron oxide at the hot ends, due to deposition from the furnace gases, there would be an actual improvement in refractories. The amount of iron oxide deposited on the hot surface, however, is sufficient to greatly reduce the refractoriness and the softening point of the material at the surface is usually found to be well below the furnace operating temperature. The dripping point of uncontaminated silica brick is well above normal open hearth roof temperatures. Kanolt found that they became fluid enough to flow at about 3,100 deg. F. and similar softening point temperatures are found for commercial products. Because of the fact that the normal impurities become reduced in amount at the hot face, it is very probable that the dripping temperature would be appreciably higher than that given if contamination were not a factor.

Shrinkage of Clay Brick

Generally clay brick shrink somewhat in firing and so if the temperature at which it is used is higher than that of the firing further shrinkage will take place. The shrinkage becomes greater as the content of alumina increases so that the so-called high alumina bricks show the effect in service to quite a degree unless properly burned at a high temperature in the kilns. This property of clay brick emphasizes the necessity of good attention to the burning in manufacture and proper selection from that standpoint for the temperatures met with in service.

THE STEEL PLANT BRICK MASON

Refractories in Power Plants*

By R. A. Sherman

Although the furnaces in some of the earliest steam boilers were entirely surrounded by the water in the boiler, furnaces lined with refractories have long been considered essential parts of boilers, and the manufacture of fire bricks for the construction and maintenance of boiler furnaces is an important branch of the refractories industry. According to the latest figures available, 20 per cent of the fireclay refractories manufactured is used in boiler furnaces, a larger percentage than in any other one type of furnace except open-hearth steel furnaces, in which about 34 per cent of the total production is used.

Now, however, the literature of the power-plant field is replete with references to "the boiler built around the furnace" in which no refractories are used. This has apparently caused some apprehension among the manufacturers of refractories as to the future status of this important market for their product.

The purpose of this paper is to discuss: (1) The reasons for this development, (2) its significance to the refractories industry, and (3) the future status of refractories in power plants.

Reasons for the Development of Water-Cooled Walls

The remarkable advances which have been made in recent years in reducing the cost of generating steam are now well known and have resulted from three principal lines of development: (1) More efficient use of fuel, (2) use of lower grades of fuel, and, (3) reduction of investment costs per unit of output.

More efficient use of fuel has been made possible by improvements in the design and operation of equipment to obtain more efficient combustion and heat absorption; and reduction of investment costs has come about through the operation of boilers at higher ratings, and the decrease of outage due to repairs.

Although the improvements in fuel-burning equipment, boilers and accessories have kept pace with the increased severity of service which results from more efficient combustion, higher ratings, and the use of lower grades of fuel, refractories have not, and the excessive cost of repairs and outage due to their failure often limits the efficiency and rating which could otherwise be obtained.

As "a chain is no stronger than its weakest link" the boiler and furnace are frequently no more reliable than the furnace lining.

When power-plant engineers found that the refractories commercially available would not withstand the extreme conditions of service they demanded improved refractories that would; and when these were not forthcoming they adopted methods to lessen the severity of conditions without decrease in efficiency.

Air cooling was first tried, the air being used for combustion; it is successful under moderate conditions but is limited in application because the thickness of wall between the flame and the air necessary for strength and the low thermal conductivity of fireclay bricks result in a low rate of heat transfer.

The next development was the protection or replacement of the refractories in the most severely affected areas by water or steam cooled surfaces which formed part of the circulating system of the boiler. These were successful, and because the rate and efficiency of heat transfer to the water or steam are high they have been extended to other parts of the furnace; in many furnaces refractories have been entirely eliminated.

Power-plant engineers have been prone to place the blame for the lack of refractories which can withstand the conditions of service entirely on the ceramic engineer and the refractories manufacturer. The justice of this accusation is questionable. The engineers should share the blame, as they should have realized that they were exceeding the safe working-limits set by the inherent properties of the materials. Reversion to the water-cooled furnace is a rectification of their error.

Significance of Water-Cooled Walls to Refractories Industry

The development and installation of the water-cooled furnace has progressed with increasing rapidity during the last three years. The Report of 1927 of the Subcommittee on Boilers, Superheaters and Economizers of the Prime Movers Committee of the National Electric Light Association shows that some type of water-cooled walls is in use or being tried by 70 per cent of the member companies which reported. They are evidently proving their worth, and their use will undoubtedly continue to increase in certain fields.

Limited Field for Water-Cooled Walls

However, the initial cost of water-cooled walls is generally greater than that of fire-brick settings; therefore, their use is limited to those plants in which conditions of operation justify the increased investment necessary to secure high efficiencies and ratings. These conditions include: High cost of fuel per ton or per unit of output of product, high load factor, and the use of fuel whose ash causes excessive slagging of refractories. Further, they can only be used with pure boiler feed water because of the danger of tube failure due to the increased rate of scale formation at the high rates of heat transfer. These conditions obtain and the field of water-cooled walls lies, therefore, among large central heating and electric-generating stations and certain large industrial power plants.

Conditions in Small Power Plants

Small public-utility or industrial power plants generally have a low load factor and therefore operate at low efficiencies because the investment in the equipment for higher efficiencies is not justified. Their refractories service conditions are not ordinarily extremely severe, or even if they are the plant can often better afford to reduce the severity by operation at lower efficiencies than to make the investment necessary for water-cooled furnaces. There is a real demand, however, for better service from their refractories. The use of plastic refractories is increasing in these plants because of the lower cost of labor for their installation.

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*Abstract of paper read at the joint meeting of the American Institute of Chemical Engineers and American Refractories Institute at St. Louis, December 9, 1927. Published by permission of the Director, U. S. Bureau of Mines. (Not subject to copyright.)

†Associate Fuel Engineer, Pittsburgh Experiment Station, Bureau of Mines.

Conditions in Medium-Size Power Plants

Between the extremes of the large and small power plants lie those plants of moderate size or of moderate severity of service, in many of which there may be an even choice between refractories and water-cooled furnaces. It may be taken for granted that the example set by the large plants in obtaining higher efficiencies and ratings will be followed in so far as economically possible and that the refractories will be called upon to stand more severe conditions than at present.

Future Status of Refractories in Power Plants

The future status of refractories in power plants largely depends, therefore, on the maintenance of their position in the plants of moderate size. There are two principal lines of progress open to the manufacturer of refractories: (1) The improvement of his product, and (2) the proper application of his present product.

Improvement of Product

Phelps* has stated, in regard to the improvement of refractories, that a study of the base materials which offer possibilities for refractory products will show that pronounced advancement in the development of these materials can not be expected. However, little information is available on the minerals formed in the manufacture or in the service of a fire brick, and it is on the relative amounts of these minerals rather than on the chemical composition of the raw materials that the properties of refractories depend.

The use of special refractories made from other than fireclays is deterred by their high cost.

Conclusion

The adoption of water-cooled walls for furnaces in those power plants in which the conditions of service exceed the inherent limitations of refractories should benefit rather than harm the refractories industry.

Manufacturers may now devote their attention to the improvement of their product and to proper application in those furnaces in which the conditions are suited to its use; and, in order to maintain their present position in that field, it appears to their interest to support an active program of research. In order to regain business in that field where it has been lost they might well engage in the further development of water-cooled refractory walls. Walls of refractories cooled by water tubes to prevent their rapid failure combine the desirable features of high temperatures in the furnace and efficient and rapid heat absorption in the tubes. The ultimate in the design of this type of wall at low cost has surely not been reached, and there is no reason why manufacturers of refractories should not contribute to and share in this development in power-plant engineering.

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*Properties of Refractories and their Relation to Conditions in Service, Stuart M. Phelps. Paper presented at First National Fuels Meeting, St. Louis, Mo., Oct. 10-13, 1927.

Tests of Refractories

The Consumer's View

C. P. Spangler, Jones & Laughlin Steel Corporation, spoke before the refractories division of the American Ceramic Society meeting regarding laboratory tests of firebrick for construction of the checker work in open-hearth and other regenerative furnaces, and explained their unsuitability from the consumers point of view.

Results of cone tests, said Mr. Spangler, are valueless to the brick consumer. These tests are made with clean flames, whereas in actual service, the brick is subjected to constant contact with gases heavily laden with dust which has a pronounced effect on the life of the refractory.

Mr. Spangler brought out that, because cone tests as indicators of what refractories will do in actual service, are not practical, it is necessary for the consumer to find out for himself what brick will best answer his requirements.

The Producers' View

F. A. Harvey, Harbison Walker Refractories Company, a member of the sub-committee of the American Society for Testing Materials, brought out that service tests based on the idea of comparative performance would have to make use of some particular refractory as the basis of comparison.

C. E. Bales, Ironton Firebrick Company, expressed the belief that it is unlikely that any laboratory test can be developed which will give reliable data of what refractories will do under different variations in service conditions.

M. L. Bell, General Refractories Company, discussed the requirements of firebrick, including refractoriness, load carrying ability, resistance to fluxing and resistance to spalling. He spoke about the behavior of firebrick in service.

The Research View

Mr. K. M. King of the Ohio State University agreed with Mr. C. E. Bales regarding the tests and S. M. Phelps, Mellon Institute of Industrial Research, Pittsburgh, told of improvements in laboratory methods of testing firebrick but expressed the conclusion that it is very difficult to approximate actual service conditions.

New Developments in Refractories

F. H. Norton, Babcock & Wilcox Company, at the meeting of the refractories division of the American Ceramic Society at Atlantic City, spoke about the construction of kilns which successfully carry a temperature of 3,000 to 3,100 deg. F., said to be the highest temperatures ever reached in brick kilns.

A. Silverman described difficulties which glass makers have with refractory pots for making boric acid glasses.

G. J. Easter, Carborundum Company, Niagara Falls, N. Y., spoke of the effect of pore size on brick as a thermal insulation. The finer the pores, he said, the less heat is lost by radiation and convection, although the degree of fineness has its limits.

SAFETY FIRST IN THE STEEL PLANT

International Safety Congress to be Held at New York City from October 1 to 5

The executive committee of the National Safety Council has decided that the Seventeenth Annual International Safety Congress is to be held at New York, October 1, 2, 3, 4 and 5. It probably will require four or five hotels to house the delegates, general meetings, industrial section sessions, breakfast, luncheon and dinner gatherings, the "smile" party, annual convention of members and the exposition of safety devices and appliances.

All of the old popular features will be maintained and several innovations will be introduced. It is expected that there will be a greater attendance than even was recorded at the Chicago gathering last fall when 6000 men, women and children were present.

Record at Joliet Plant of Illinois Steel Company

From the date of the third lost time accident during the month of April 1927, all departments, the entire Joliet Works Plant were successful for the next 256 consecutive day period or the longest consecutive period of days thus far recorded for the entire plant without a single lost time accident being caused, thus establishing a new and remarkable "No Lost Time Accident Record" for the pioneer plant in accident prevention.

As Safety Director at the Central Alloy Steel Corporation Mr. J. A. Voss must look after the safety of all employees, but he also finds time to attend to his duties as chairman of the Publicity Committee of the National Safety Council.

Human Waste—Prevent It

By Eugene S. Grace

To eliminate waste wherever it exists is one of the greatest contributions we can make to our company and to ourselves. This is the challenge which is now facing business all along the line from the production to the consumption of the things we use. Our ability to make substantial savings in time and materials has been tried and proven. We have made great strides in manufacturing economies during the last few years, but there still remains much that can be done especially in further reducing the human and economic waste caused by accidents.

A man who is hurt suffers pain and worry; his family loses a part or all their income. No inducement should be necessary to encourage employees to use the utmost care and vigilance to avoid injury and save lives.

No Spare Parts

"When God made man, he made no spare parts. Your hands, feet and eyes cannot be duplicated." —The Mixer.

Paint Spraying

Spray Coating — Hazards and Safeguards is a 37-page pamphlet by the Hartford Accident & Indemnity Company, Hartford, Conn., reviewing the items of hazard and ways and means of the prevention of accident.

Photographic Competition for Amateur Photographers

The following cash prizes will be awarded for the best accident prevention prints:

First prize	$50.00 in gold
Second prize	25.00 in gold
Third prize	20.00 in gold
Fourth prize	15.00 in gold
Fifth prize	10.00 in gold

Ten prizes of $5.00 each
Ten prizes of 3.00 each

Pictures can be taken at any time, but entries must be in on or before July 16, 1928.

Address all communications to Photo Contest Secretary, National Safety Council, 108 East Ohio Street, Chicago, Ill.

Wheeling Steel Corporation Safety Record

P. F. Haberstick, safety director of the Wheeling Steel Corporation, before a recent safety meeting stated that accidents in the plants of the Wheeling company have been cut down 80 per cent. In the past year not one single fatal accident occurred in the plants of the company, and in two of its plants that employ over 4000 men and women, there were only 12 accidents. This is a good record both for the safety work of the company as well as for the thoughtfulness of the employes.

Bend the Nails Down

If you find a board on the ground with nails projecting, stop long enough to turn it over, with the ends of the nails down, or better still bend the nails down so they do not project upwards.